Methodological Approaches in the Development of the Meson Theory of Yukawa in Japan*)

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In this article we shall give a brief account of methodological approaches and the circumstances around Yukawa's proposal which made the backgrounds of the development of the meson theory in Japan. With the remarkable discovery of the meson theory of Yukawa, one might compare it to the sudden appearance of beautiful flower in the sterile ground. The real state of affairs was just the reverse. The fertile ground had already been cultivated enough to allow its natural growth. With regard to the role of the methodology in the development of physics, we are reminded of a compass for a traveler in the desert no man has ever explored.

1. We shall now recall the history of theoretical physics in Japan and think about what has been achieved before Yukawa.

First, we should mention an atom model with a nucleus as proposed by H. Nagaoka.[1] This proposal was presented in the year 1903. The other atomic model without a nucleus was suggested almost at the same time by J. J. Thomson,[2] an English physicist of great calibar. According to Nagaoka, an atom should consist of the positive charged massive nucleus at its center, a number of electrons revolving around the nucleus in the ring shape. The ring of these electrons in turn will vibrate in various ways of mode, which leads to many spectral lines, emitted from the atom in various kinds of vibration periods, corresponding to each of the patterns of vibrations of the ring of the electrons.

This atomic model is called thereafter a Saturn model, which is somewhat different from an atomic model of the solar system. Further, by using the Maxwell theory of the Saturn ring, Nagaoka calculated on his atomic model the vibration frequency of the ring of the electrons revolving round the nucleus. In 1911, Rutherford proved the validity of an atomic model with a nucleus. This conclusion have led to support of the Nagaoka model of an atom with a nucleus, and to exclude the Thomson model of an atom without a nucleus. The main difference between Rutherford[3] and Nagaoka was their estimation on the number of electrons contained in an atom. Whereas both Nagaoka and Thomson speculated thousands of electrons,

*) A part of author's article in the book, *Shin-ri no Ba ni Tachite* (In the Course of Our Study) by H. Yukawa, S. Sakata and M. Taketani, the Mainichi Press, Tokyo, 1951.

Rutherford estimated that electrons in an atom are few. Later, N. Bohr[4] clarified that the lightest atom, hydrogen atom has only one electron. This fact, however, invoked a grave difficulty. If an atom has only one electron, line spectra with several kinds of vibration frequencies are not expected on the basis of the classical electrodynamics. Also, such an electron revolving around a nucleus could not go on the fixed orbit. In this way, atomic physics meets the decisive difficulty. In fact, with the classical electrodynamics we cannot understand an atom. In 1913, N. Bohr[4] solved this difficulty by introducing a new quantum theory. This event occurred after ten years when Nagaoka first suggested an atomic model with nucleus in the detailed formulation.

The fact that a Japanese physicist achieved this successful result at the very starting point of the atomic theory gave a great impetus to the contemporary physicists in Japan.

It is greatly regretted that any successor after Nagaoka did not follow. One of the main reasons may be the fact that then a feudalistic atmosphere covered the academic circle and new activities were suppressed. When Nagaoka presented his atomic model before a meeting of the physical society in Japan, great professors at that time charged that such a theory of an atom is a metaphysic and not a scientific work. And Nagaoka was discouraged and turned to the study of magnetism.

The second achivement in this field was brought about by Jun Ishiwara.[5] He was the first of the theoretical physicists in Japan, with a different character as compared to that of Nagaoka. Ishiwara was attracted by Einstein and his several works of the relativity theories. In 1911, Ishiwara went to Germany from Tohoku University, and studied the theoretical physics under the guidance of A. Einstein and A. Sommerfeld and became an acquaintance of Max von Laue and returned to Japan. He[6] worked on the relativity in 1915. In 1911,[5] he wrote a paper discussing the validity of the quantum theory of photon. Further in 1915,[7] by introducing the generalized coordinate system he formulated the quantum condition which is a basic formalism for the quantum theory of the atom. His formula served as a correct theoretical background for the atomic physics. His work was published earlier than the analogous works by Sommerfeld.[8] And his theory played an important role when atomic physics of the early quantum theory were constructed for various general cases. In this way his contribution provided a useful representation, which served as a bridge passing into the new quantum theory. Although he had contributed much to the development of theoretical physics in Japan, he was expelled from the university because of his personal love affairs. It so happened in the feudalistic atmosphere of the imperial university in Japan at that time. After leaving the university he was engaged in the enlightening works and science reviews. He edited the scientific Japanese journal *Kagaku* (which means science) of the Iwanami Publishing Company. No one can deny the merits of his activities, in addition to his research works, for the promotion of the scientific level of Japan and for the building up of active circumstances.

We must call attention to the fact that two kinds of workers of importance exist in the scientific fields. First, we have to mention the supreme workers of his own research. Second, we must not forget the man of the organizer type, whose existence leads to and create a highly active circumstance, resulting in a number of remarkable works around him. We may cite as such examples, N. Bohr, A. Sommerfeld and J. R. Oppenheimer. It may also be said that Ishiwara contributed to provide a fertile land for the later development of theoretical physics in Japan. Many theoretical physicists now working as the backbones in Japan have been influenced by Ishiwara. We consider that such works as that of Ishiwara should be fully appreciated.

Third, Y. Nishina appeared as a theoretical physicist whose works are accepted internationally. Nishina studied the theoretical physics at Copenhagen under the guidance of N. Bohr. After returning to Japan, he constructed in 1931, the Nishina laboratory in Rikagaku Kenkyusho (Institute of Physical and Chemical Research, Tokyo), and started the studies of the nuclear physics and the cosmic rays. He is known as one of the workers who calculated the so-called Klein-Nishina[9] formula published in 1929. Klein and Nishina studied by using the Dirac equation the scattering of γ-rays by the electron. The resultant formula were later proved to agree with the experiment. This gives us the important proof in favor of the Dirac theory over the former theories. In this way, the works done by Nagaoka, Ishiwara and Nishina were noticed in the international community.

2. Soon after I became a student of the third class of the university of Kyoto, the so-called 'incident of Kyoto University' happened to occur. At that time Hatoyama, the Minister of Education, submitted Takikawa, professor of Laws, without the agreement at a formal meeting among the professors of Faculty of Laws. There was an atmosphere of resistance against this 'incident'.

When I was discussing this incident among my friend, I was enlightened that the way of approach of the Minister of Education was entirely wrong. This should be classified as the analogous type of oppression of knowledge by Nazism, which had just been undertaken in Europe. In fact, when Nazism had succeeded in Germany, many precious books of a prominent international reputation in the cultural world were burned. Also many famous scholars of physics and other branches of science who had been adored by us all were expelled from their positions. We thought that the analogous absurd events were undertaken by the followers of the military forces in Japan. Previously in 1931, Japanese military forces had invaded the Manchu territory of China ('Manchu-incident') and the military fascism had enforced their powers increasingly.

Around the year 1934, when I graduated from Kyoto University, the progress in the physics of elementary particles was radical. First the neutron was discovered in 1932 by Chadwick. This discovery led to the clarification of the structure of nucleus and various difficulties about the understanding of nucleus were solved in terms of the new nuclear model, which includes neutron as one of the constituents. Second, the positron was discovered by Anderson in the cosmic rays and by the Joliot Curies in the radioactive nuclei. Informidable difficulties in relation to the electron theories were solved before the discovery of the positron. These two facts influenced me with a grave implication. I now had to reconstruct my opinion, on an entirely new standpoint, about what logic of science is.

At that time, the line of thoughts of the neo-Kantianism and Machism was prevailing in the current review of science. It was thought that physics will find the laws by arranging the empirical facts, and only the sense-composite is real existence, all the remained being constructed by the subject by means of arranging the experience. Also, it was said that the essence of science lies in the function and, therefore, in the course of the development of science, the substance will be absorbed in the function.

The science review by J. Ishiwara and H. Tanabe (leading philosopher, famous professor of philosophy, Kyoto University) was more or less along these lines of thoughts. If these thoughts were to be applied to physics, it would be nonsense to consider what the internal structure of nucleus, whose diameter is only about 10^{-12} cm is, and what the structure elements of nucleus are. It is not the role of science to arrange mathematically various phenomena which come out concerning nucleus. The actual ways along which physics was developed were completely different. So long as the correct model of the nucleus was not presented, all knowledge related to the nucleus was in confusion. However, when a new substance, the neutron, was discovered and the correct model of the nucleus was settled, the confused situation was resolved and the systematic perspective was opened on nuclear physics. With regard to the positron, it happened analogously. Before the positron was discovered, the electron theory by Dirac had been beset by mysterious difficulties. Once a new substance, the positron, was discovered, all questions were solved at one blow, and the knowledge was systematized. As a result, with the Dirac theory one could deal with various phenomena on the far-reaching viewpoint. I noticed that similar events happened in the cases of the recognition of the solar system, and of the construction of the atomic theory. Further, the theory of β-decay was constructed along the same line of attacks. N. Bohr suggested that the conservation laws of energy and the other quantities might be lost in the interior of the nucleus. This suggestion led to the breakdown of the rational theory in nucleus. However, Pauli in 1931 proposed the rational theory by which new particle, the neutrino, should accompany the electron in β-decay. This proposal was meant to solve the difficulties of β-decay reasonably. Fermi formulated this theory by utilizing the method of the radiation theory and succeeded to make the complete theory of β-decay. In this case, the introduction of a new substance, the neutrino, rescued the confusion of the theory, and enabled us to treat theoretically the phenomena of β-decay which had been so impregnable. In this latest problem, I was convinced that the validity of a new way of thinking on the methodology of science was powerfully proved.

I had an occasion to visit Sakata (April 1934) who had just procured a position at Osaka University under Yukawa. I obtained, there, information on the new topics and discussed it with Yukawa and Sakata. This chance alone afforded me a clue how to attack the new problems. At that time, I met the two problems:

First, the current reviews of science were incompetent for the new development of physics. I have to explore and build the methodology and the logics which may be useful for promoting the studies of the nuclei and the cosmic rays. This is meant to meet the future development of physics.

Second, the development of the quantum mechanics had a profound influence on the contemporary philosophy. It seemed, however, that the interpretation of the quantum mechanics made by philosophers was, in any case, superficial and did not come in touch with its essence. I felt the necessities to seek the philosophy which enables us to realize correctly the new states of matters, by taking up the new logics from the quantum mechanics. To do this I studied the mathematical foundation of the quantum mechanics.

Sakata was very kind and helped me to investigate these problems. He is well acquainted with the natural dialectics. I had already studied various schools of philosophy and investigated them by their application to my problems. And I was led to conclude that I have to study directly from the originals and not through the interpretation by Japanese philosophers at that time. When I came in intimate contact with the original works by the great philosophers, I felt that my long standing questions were solved. This is the real method of attacking science, I thought. I have managed to conquer my idealistic philosophy step by step, by means of the complicated ways of studies and with the unexpected surprise. (See the problems of the dialectics, M. Taketani,[10] in this book, p. 27.)

3. Now I am in the position to discuss the process of the construction of the meson theory of Yukawa. At that time, the problems of nuclear force and β-decay were mainly attacked from the phenomenological side. On the other hand, the field theory was developed and many sophisticated trials

were welcomed. Only a few attacked the problems of β-decay and nuclear force from the fundamental view point.

First, Fermi[11] treated the theory of β-decay on the basis of the field theory by using the neutrino hypothesis. Second, Tamm and Iwanenko[12] calculated the nuclear force by using the Fermi theory of β-decay. They gave the short range nuclear potential in terms of a model, in which the nuclear force should be derived by the interchange of the electron and anti-neutrino between the proton and neutron. However, the resultant strength was negligibly smaller than that observed by a factor of 10^{-15}. Again, the problem met with informidable difficulties. Bohr[13] was in favor of the view-point that the quantum mechanics cannot be applied to the electron in the nucleus, and also rejected the Fermi theory. Especially, he was not happy about the hypothesis of the neutrino which had not yet been observed. N. Bohr's inference that energy is not conserved in the nuclear region was further pushed by the β-decay theory of Beck and De Sitte (1933) using the mechanism of pair-creation. At that time, it was generally considered that the system of law itself was wrong. There were few who had an idea that a new substance should be introduced. Instead, they warned of the speculation of introducing a new substance. It is not the problem of the talented physicists who have enough experience as specialists, to induldge in such a speculation. It is the business of dilettante. A professional physicist must rely on the available material, already confirmed by experiments, and must conquer the difficulties in terms of the specialized, highly mathematical techniques. This was the current tendencies among physicists. It is interesting to see that nowadays in the elementary particle physics, the analogous tendencies are noticed before the difficulties about the internal structure of elementary particles and the various new phenomena which are to be understood.

Yukawa started from the theory of Heisenberg[14] who assumed that proton and neutron are constituents of nuclei. He first imagined that a neutron (proton) will change into a proton (neutron) by emitting an electron (positron), leading to nuclear force. He could not, however, obtain the reasonable result from this assumption on the quantum mechanics. The model of the nuclear force by Heisenberg had in this respect some defects. Then Yukawa was informed of the Fermi theory of β-decay, and was impressed by its far-reaching theory. Sakata also accepted the Fermi theory on his standpoint of the natural dialectics by which the mysterious principle by Bohr had been criticized and the reasonable principle by Fermi was welcomed. Sakata[15] had in Tokyo already studied with Tomonaga[15] the pair creation by nuclei before the γ-ray is emitted. Yukawa and Sakata[16] applied the Fermi theory and discovered the mechanism of electron capture by nucleus. The process was later proved by the experiment of Alvarez.[17] In this way Yukawa worked very actively by getting the wonderful coworker, Sakata.

When Yukawa studied the calculation of Tamm and Iwanenko who estimated the nuclear force by assuming that the exchange of electron-anti-neutrino pair between the proton and neutron will lead to the nuclear potential of a short range he was greatly excited. Before the difficulties that the result obtained by Tamm and Iwanenko was too small to give the strong nuclear force in terms of the weak beta-decay interactions, Yukawa took the way of getting out by introducing a new substance. In his method of attack, he was against the current ways of attacks.

According to Yukawa,[18] an entirely new field must be introduced in order to derive a strong nuclear force. Further, the quantum of such a field must have big mass enough to give a short range potential. (The mass of the quantum was estimated to be $\sim 200\, m_e$, m_e being the mass of electron). For this field he gave the name of '*U*-field or heavy quantum'. The *U*-quantum should have an electric charge $+$ or $-$, in order to derive the nuclear force between the proton and the neutron. With regard to the β-decay, the *U*-field will act as an intermediary: First, the proton (neutron) produce $U^+(U^-)$, then $U^+(U^-)$ will decay into $e^+ + \nu(e^- + \tilde{\nu})$.

Just as the light quantum plays an important role in the domain of atoms and molecules, resulting in the quantum theory, this new heavy quantum will play a new role in the nuclear domain.

The above is an outline of the revolutionary idea of Yukawa. The article was completed in October 1934, and presented before the annual meeting of the physico-mathematical society, which was held on November 17, and published in the next year issue of the journal.

The work by Yukawa was at that time not recognized by any one. It was partly because the society of Japan was not well known abroad. But the main reason why it was neglected should lie in the fact that such a quantum had never been observed. No one was willing to accept a theory which was based on the existence of an unknown particle. In Japan, no people accepted the Yukawa theory, except Nishina and Tomonaga. Of course, we around him welcomed it, because the Yukawa theory can be considered as a new example to prove the validity of our methodology. The Yukawa theory remained still vague and yet to be fully developed, but the ambition and plan were the grandest among all other theories.

If we look back over that time from now, we must agree that the introduction of a new particle is natural and not a risk. And one may regard that the methodology was not necessary for that. However, we have to be reminded of the atmosphere at that time. In order to make a choice among many possible ways, we need a correct methodology in order to settle which way will lead to the truth. Since the way then followed turned out to be correct and natural, the methodology may be regarded as surplus when it is looked back afterwards. However, the way which could be afterwards considered to be correct would be reached only in terms of the methodology. If we do not establish it as the methodology, it could not be useful when the unknown domain should be explored. The people who never really strayed in the dark domain, and were only engaged in the interpretation, could not understand its true value.

4. In Kyoto, many young workers in various branches organized a research group outside the university and started to make lively discussions about the resistance movements. They edited and published the journal *Sekai-Bunka**) in January 1935. I joined this group and took part in the discussion among many people in different fields of culture. And to that journal I contributed by writing several topics of the contemporary physics and the methodology. Meanwhile, military activities in Japan were at that time becoming explicit. Mysterious imperialism swayed the whole nation and the special police controlling public thought became stern. In Europe, the pressure by Nazis grew ever stronger, and in resisting this pressure an anti-fascism movement was organized. In France, a battle-front for people won and began to construct the government, and to execute their progressive plans.

Fascism in Japan will destroy the culture and research activity of Japan. If we could not stop fascism in any way, we would find that our learning falls down following the history in German. On these viewpoints, *Sekai-Bunka* published, on one hand, papers to describe the situations of new research activities, and also on the other hand, introduced enthusiastically the cultural movements which were made by the battle-front of people against fascism in Europe. The activity of *Sekai-Bunka* was meant to contribute a little in any way to the resistance against Japanese imperialism which was just preparing for the invasion into the Chinese continent. Nakai said that if we allow Japanese militarism to invade the continent, our Japanese intellectual class would be ashamed.

I have been endeavoring to find the way of exploring physics. Especially, my concern was to establish the methodology which is useful in promoting the actual research, and was not the interpretation of physical achievements, as was done by the current philosophy.

In this journal, *Sekai-Bunka*, I have published papers on the logical structure of quantum mechanics (1936), and that on the three-stage theory of the development of physics. Sakata has spoken admiringly of these papers.

We started by considering the various possibilities for the speculated meson, in order to develope the Yukawa theory. First, we raised a question whether the nuclear force in every respect could be derived by the meson

*) *Sekai-Bunka* in Japanese means "World Culture".

theory. Thus, Yukawa and Sakata[19] calculated the nuclear potential by the fourth order perturbation. And it was found out that with the charged scalar meson the results are not satisfactory. In this calculation, the quantized scalar meson field formulated by Pauli and Weisskopf[20] was firstly used, and it was revealed that the sign of the nuclear potential given by the first paper of Yukawa was of the opposite sign. In view of this result, they suggested that the neutral meson is necessary in addition to the charged mesons. Second, I was paying attention to the anomalous magnetic moments of nucleon. By means of the correspondence principle, I was led to suggest that spin of the meson is 1, if the magnetic moment could be drived by the meson field around nucleon. Just before that time, Yukawa and Sakata had formulated the generalized Dirac equations with spin greater than 1. We in this occasion agreed to prepare the third paper of the meson theory by Yukawa, Sakata and Taketani.[21] In this paper, the neutral meson was naturally introduced as a partner of the charged mesons in the symmetric meson theory.

In spring of the year 1937, N. Bohr visited Japan and gave us very exciting lectures on the quantum mechanics and the role of the observation. His enthusiastic and sincere attitude impressed the audience.

In Kyoto, Yukawa and Nishina met with N. Bohr. Yukawa talked to him about the meson theory, on which Bohr was not attracted. He asked Yukawa, "Why do you want to create such a new particle?" At this question, we all were not happy. However, before Bohr returned to his native country from Japan, we were informed from the United States that a new charged particle having mass of $\sim 200\,m_e$ (m_e being mass of the electron) was found in the cosmic rays by Anderson and Neddermeyer,[22] and also by Street and Stevenson. In the Nishina laboratory of the Institute of Physical and Chemical Research (Tokyo), Takeuchi examined the photographs obtained by the cloud chamber and found the tracks of the new particle. Its report was published in the September issue of *Kagaku* by the name of the experiment of Nishina, Takeuchi and Ichimiya.[23] We thought 'The predicted particles is at last discovered'. The difficulties of the nuclear theory are solved by the discovery of a new particle. They are not solved in terms of the modification of the system of the laws such as the electron theory or the quantum electrodynamics, which had been expected by the majority of physicists.

Yukawa[24] published a short note in the Japanese Journal (*Proc. Phys.-Math. Soc. Japan*), entitled "On a Possible Interpretation of the Penetrating Component of the Cosmic Ray". In this note he suggested that the new particle may correspond to that predicted by himself in 1935. With this event, we were greatly encouraged, and absorbed in further development of the meson theory.

Throughout these attacks in the darkness, it was the three-stage theory of materialistic dialectics that showed us the way of research and gave us the belief to conquer the difficulties. At that time we had the following viewpoint on our methodology: In contrast to the current opinion that the difficulties of the nuclear theory lie in a deficiency of the quantum mechanics itself, we take the standpoint that the problems of the meson theory should at the present be attacked within quantum mechanics by using the correspondence principle. This is our substantialistic method. We regarded that nuclear physics in those days was at the substantialistic stage where the main problems are the investigation of what are the constituents of the substance under consideration, and also on what are the properties of the constituents, and not speak of the difficulties of the quantum mechanics. We felt that we were still far from the stage where the quantum mechanics should be fundamentally modified.

When we established the formulation of the spin 1 meson, we were informed that Proca[25] had already worked out the same equation as ours, and the quantization was made in USSR. In this way, against the confusion of the nuclear theory, we were able to analyze the reasons of the tremendous difficulties step by step. We arranged the problems in good order. This was the merit of our way of attack on the three-stage theory on the materialistic dialectics. Otherwise with the idealistic Machism we might be lost, even falling into the overall denial of the theory.

Sakata was steady and had a sharp analyzing ability, Yukawa was endowed with the smart thinking making a point in the complicated matters. When the new formulation was developed and the academic, mathematical formalism was persued, Yukawa's comment to turn into physical aspects was presented. Further, Sakata was a genius for organizing people to make collaborated works. No one feels a hostile feeling against him. He will always construct an atmosphere of agreement among people by speaking his opinion frankly.

In the end of February, after our paper was completed, we read in the January issue of *Nature* analogous works published by H. J. Bhabha,[26] N. Kemmer,[27] and also by H. Fröhlich and W. Heitler.[28]

5. In the summer of this year, the military forces of Japanese imperialism started to invade the Chinese continent. It seemed to be in vain that we worried and resisted Japanese imperialism, although we were not able to do much. The Special High Police suddenly enforced a strict observation, and the general tendencies of the newspapers and radio-broadcasts were to jump into the militaristic atmosphere within a night. With a gloomy feeling I was engaged in studying the development of the meson theory.

In the autumn, active members of the publishing group of *Sekai-Bunka*, with whom I was collaborating, were suddenly arrested by the police. The

Sekai-Bunka was entirely a legal journal and the circulation was never prohibited nor the journal was warned previously by the police. Inspite of such careers why had they been arrested point-blank? Anyhow, it was obvious that we could not continue to publish the journals. We thought that before this crisis we must not sway our conviction to fight against fascism. I considered a counterplan with Keinosuke Kobayashi in his apartment. He was a biologist and jointed the activities around the *Sekai-Bunka* with us, after the incident of Kyoto University.

During the period of my intensive research work on the meson theory, I felt that the peril of the pursuit of the Special High Police was imminent. In order to escape this danger, I left Kyoto in the winter of 1938 and lodged with an acquaintance in Kobe. We called such removal of lodging by the name of seeking refuge. It happened that I could meet with Yukawa and Sakata more frequently because they lived near Kobe, and this enabled us to conduct coordinated research.

During the end of June 1938, a girl friend of Kobayashi brought me his letter at my lodging, informing me that the remaining members of the *Sekai-Bunka* were all arrested on June 26. According to the report of some journalists, Taketani was also to be arrested. Truthfully, I was not arrested because I had left Kyoto and moved to Kobe and, therefore, escaped from the police pursuit. If I had been arrested in the autumn of 1937, I could not have joined the collaborated works on the meson theory. I found that I became a fugitive with a premonition of being arrested at any time. I could not waste my precious time. I had to do as much as possible.

Three days after I changed my lodging again in Kobe, a few plainclothes men forced themselves into my apartment while I was asleep and arrested me. It was six o'clock in the morning of September 13. I was detained at the Fukiai police station, and later was taken to Kyoto and held at the Uzumasa police station. There I met Takeshi Shimmura who had just finished being interrogated by the police. He informed me of the whole situation. After one month I was taken to the Kawabata police station which was responsible for the investigation of Kyoto University. There the police began the investigation of my case. In the form of a memorandum, I had to make a detailed account of my activities with the *Sekai-Bunka*, beginning with the change and development of my thoughts and the interrelations of several events. My unlawful acts were the followings: my analyses on the quantum mechanics, my analyses on the development of the nuclear physics and my methodological approach of the meson theory, in short, my research activities on the natural dialectics. They forced me to state that, with the natural dialectics I had participated in the cultural movement of the people's front under the instructions of Komintern, thus helping the promotion of the Japanese Communist Party.

At that time I was an assistant (without salary) at Osaka University and also in the same position in Kyoto University. Around the end of October my brother came to visit me at the police station and informed me the intention of the universities that they were not happy if I continued to occupy my positions. Sakata on the other hand tried to conceal my arrest from the universities, and further made an attempt for my release. However, when the university was informed of my arrest, they wanted my resignation instead of making an effort for my release. It was an eyesore for them that I occupied the assistantship even without salary. Soon I resigned. In February the investigation by the Special High Police ended. I was allowed to study in the investigation room before the inquiry by a public prosecutor started. Also I was allowed to communicate with Sakata about physical problems and to read photocopies of the latest research works which were sent to me by Sakata. I was not allowed to bring them in the cell but I dared even to study them in the cell by hiding under the blanket. I sent a letter to Sakata from the police station, telling him that we have to consider separately the life-time of the meson and the life-time of the nuclear beta-decay. In the investigation room, I calculated exactly the magnitude of the coupling constant of the strong interaction for the nuclear force. By inserting it I was led to the better result for the life-time of meson. About one week later, I accepted a typed paper by Yukawa and Sakata in which the analogous result was made by them. It gave me a pleasure to find a coincidence of our results, which were obtained quite independently with each other.

In April of 1939, the investigation by a prosecutor was made on my case. I showed him a number of our papers which had already been referred to by workers in foreign countries. He seemed to have realized a little, the merit of our works in physics. After several days, he summoned Yukawa, and freed me under a suspension of prosecution, and under the guarantee of Yukawa.

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