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Chinese Physicists' Construction of the Straton Model in Social Context[1]

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Abstract: In 1956, disciplines including nuclear technology and research on nuclear and elementary particles were added to the P. R. China's national program for science and technology development. Mao Zedong explicitly supported Shoichi Sakata, a Japanese physicist, in applying materialistic dialectics to physics research, which influenced Chinese scientists in their study of particle physics. Starting in the early 1960s, physicists from the Institute of Atomic Energy, CAS, the Institute of Mathematics, CAS, Peking University, and University of Science and Technology of China put effort into the theoretical research of elementary particles and gradually formed a collaborative research group. From 1965 to 1966, they analyzed the experimental results and existing theories available to them, made a connection between their work and Mao Zedong's belief that matter can be infinitely divided, and put forward the straton model, a structure model of hadrons. In July 1966, the straton model was presented at the Summer Physics Colloquium of the Peking Symposium. Unfortunately, scientific research in China soon came to a halt due to the Cultural Revolution (1966–1976); the academic exchange between Chinese scientists and their foreign peers became even more difficult than before. The calculation results of the hadron model failed to be formally published in English as Chinese scientists had wanted. As a result, the model did not have the kind of influence upon the development of particle physics at the international level that these scientists had expected.
Keywords: the straton model, particle physics, Chinese physicists, Mao Zedong

The development of experimental devices and methods helped particle physics break away from nuclear physics and grow to be an independent discipline (Brown, Dresden, and Hoddeson 2009, 5). In the mid-twentieth century, particle physics entered a stage of rapid development. The rate at which new particles were discovered left particle physicists with an urgent need to classify more than one hundred kinds of

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particles, to figure out their underlying relations as well as why such relations exist, and to put forward new conceptual and theoretical models. In the newborn socialist country, Chinese physicists proposed a structure model of hadrons called the straton model. Its development provides a case study of how scientific theory comes into being within a specific social context, and will help us understand the development of physics—and even natural science at large—between the 1950s and the 1970s in China.

1 The formation of a particle physics research team and the development of research questions

The transmission and development of modern physics in China started at the beginning of the twentieth century. Its institutionalization was gradually realized after students were dispatched to study physics in foreign countries, schools and research institutions were established, and student organizations were started (Dai 1993, 1). Students who went to Europe or the United States during the 1910s and 1920s, such as Y. H. Woo 吴有训 (1897–1977), Chi-sun Yeh 叶企孙 (1898–1977), Tsi-ze Yan 严济慈 (1901–1984), Chou Pei-yuan 周培源 (1902–1993), and S. C. Wang 王守竞 (1904–1984), made contributions to a number of branches of physics, including X-ray scattering, measurement of the Planck constant, spectroscopy, relativity theory and cosmology, and quantum mechanics.[3] After returning to China, they made a great effort to train students in physics and recommended some of them to go abroad to study modern physics.

The theoretical research of particle physics started relatively late in China, mainly with the efforts of Chang Tsung-sui 张宗燧 (1915–1969), Ma Shih-chün 马仕俊 (1913–1962), Peng Huanwu 彭桓武 (1915–2007), Hu Ning 胡宁 (1916–1997), and Tzu Hung-yuan 朱洪元 (1917–1992) when they returned from studying in Europe or America during the 1930s and 1940s. While they were abroad, as students of R. H.

3 Y. H. Woo 吴有训 went to study at the University of Chicago in 1921. He made great contributions to the discovery and acceptance of the Compton effects. For Woo's representative work, see Woo 1926.
Chi-sun Yeh 叶企孙 went to the United States in 1918. He transferred to Harvard University after obtaining the bachelor degree from the University of Chicago in 1920. At Harvard, he measured the Planck constant h under the guidance of W. Duane (1872–1935). For Yeh's representative work, see Duane, Palmer, and Yeh 1921.
Tsi-ze Yan 严济慈 went to the University of Paris in 1923 to research the piezoelectric effect of quartz under the guidance of C. Fabry (1867–1954). For Yan's representative work, see Yan 1928.
Chou Pei-yuan 周培源 went to the University of Chicago in 1924. For Chou's representative work, see Chou 1937.
S. C. Wang 王守竞 went to the United States in 1924 and studied successively at Harvard University and Columbia University. He succeeded in applying the newborn quantum mechanics to the research on the problem of normal hydrogen molecule. For Wang's representative works, see Wang 1928 and Wang 1929.

Fowler (1889–1944), W. Pauli (1900–1958), M. Born (1882–1970), P. S. Epstein (1883–1966), and P. M. S. Blackett (1897–1974), respectively, they had made influential contributions to areas including the mathematical form of quantum field theory, meson theory, dispersion relation and synchrotron radiation, among others.[4] Around the time when the P. R. China was founded, Chang Tsung-sui and some other physicists returned to their homeland and devoted themselves to developing particle physics in China. Back then, however, the Chinese government did not pay as much attention to basic research as it did to applied science. Chang Tsung-sui and his colleagues failed to carry on the theoretical physics research that they had been doing while they were abroad; only a small amount of their work upon returning had something to do with the mathematical form of quantum field theory (Dai 2009).

In September 1952, Mao Zedong 毛泽东 declared that China would finish its transition to socialism within ten to fifteen years (Bo 1993). Later on, in line with this goal, the central government formulated development plans for different lines of work. In 1955, following the suggestion of V. A. Kovda (В. А. Ковда) (1904–1991), the Soviet

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4 Chang Tsung-sui 张宗燧 went to the University of Cambridge in 1936 to study statistical physics under Fowler's guidance. Between September 1938 and the end of 1939, Chang worked successively at the Institute for Theoretical Physics of the University of Copenhagen headed by N. Bohr (1885–1962) and the Swiss Federal Institute of Technology Zurich. Meanwhile, he was doing research on quantum field theory and particle physics under the guidance of C. MΦller (1904–1980) and Pauli. For Chang's representative works, see Chang 1942, and Chang and Wilson 1940.
Ma Shih-chün 马仕俊 went to the University of Cambridge to study meson theory and W. H. Heitler (1904–1981) was his collaborator. In 1941, Ma Shih-chün returned to China and started to teach relativistic quantum mechanics, electrodynamics, and so on at the National Southwest Associated University. After 1946, Ma Shih-chün worked successively at the Institute for Advanced Study in Princeton, the Dublin Institute for Advanced Studies, the Institute for Nuclear Studies in the University of Chicago and the National Research Council of Canada. For Ma's representative work, see Ma 1947.
Peng Huanwu 彭桓武 went to the University of Edinburgh in 1938 to study solid-state physics under the guidance of Born, one of the founding fathers of quantum mechanics. From 1941 to 1943, Peng Huanwu was a postdoctoral fellow at the School of Theoretical Physics in the Dublin Institute for Advanced Studies, where E. Schrödinger (1887–1961) was the director. There Peng Huanwu worked with Heitler to explore meson theory. From 1943 to 1945, Peng Huanwu was back at the University of Edinburgh doing research on the divergence problem in quantum field theory in collaboration with Born. For Peng's representative work, see Hamilton, Heitler, and Peng 1943.
Hu Ning 胡宁 went to the California Institute of Technology in 1941 to study quantum theory under Epstein's guidance. In 1943, he went to the Institute for Advanced Study in Princeton to do research on meson theory of nuclear force and general relativity under the guidance of Pauli. Between 1945 and 1950, he visited institutes and universities including the Dublin Institute for Advanced Studies and the Institute for Theoretical Physics of the University of Copenhagen. For Hu's representative works, see Hu 1945, Jauch and Hu 1944, and Pauli and Hu 1945.
Tzu Hung-yuan 朱洪元 was doing research on synchrotron radiation and elementary particles in the cosmic ray research group led by Blackett in the University of Manchester from 1945 to 1948. For Tzu's representative work, see Tzu 1948.

science consultant of the academy's president, the Chinese Academy of Sciences (CAS) made a proposal to the State Council that a fifteen-year plan for scientific research should be formulated, and started drafting this plan. In January 1956, Premier Zhou Enlai 周恩来 mapped out the guidelines for formulating a long-term plan for national science and technology development in a meeting about intellectual issues (Zhou 1994). In the "1956–1967 nian kexue jishu fazhan yuanjing guihua gangyao" 1956–1967 年科学技术发展远景规划纲要 (Outline of the national program for science and technology development [1956–1967]), which was formulated in the same year, fifty-seven important research tasks sorted into thirteen themes were proposed (Anonymous 1994). The theme called "new technology" included seven important tasks, such as "the peaceful use of atomic energy," "the establishment of jet and rocket technology," and "research on radio electronics and the related new applications." Three disciplines, namely nuclear and elementary particles physics, radio physics and electronics, and semiconductor physics, were listed as priorities for the development of physics, while basic research on field theory and quantum mechanics were included in the fifty-sixth task, "research on certain fundamental theoretical issues of modern natural sciences."[5] In 1957, the news that T. D. Lee and C. N. Yang won the Nobel Prize in Physics encouraged a number of students to choose particle physics as their major. In that year, and subsequently in 1963 and 1964, graduate schools enrolled new students on a small scale, adding to the overall number of particle physics researchers. In order to disseminate theoretical knowledge and train professional researchers, the Department of Physics at Peking University offered a course on quantum field theory in 1958. In the following year, Prof. Wang Pu 王普 from Shandong University in Qingdao organized a workshop of quantum field theory. Prof. Tzu Hung-yuan from the Institute of Atomic Energy, CAS, was the lecturer for both the course in Peking University and the workshop in Qingdao. In 1960, written on the basis of course materials, he published his work *Liangzi changlun* 量子场论 (Quantum field theory), which was regarded as the "primer" on quantum field theory in China. This put an end to the reliance on physics books from the Soviet Union and academic periodicals from the Western countries for introducing Chinese students to the development of particle physics.

In the early 1960s, Tzu Hung-yuan from the Institute of Atomic Energy, CAS, Hu Ning from Peking University, and Chang Tsung-sui from the Institute of Mathematics, CAS, each led a group of young researchers in conducting research on the theory of elementary particles. Tzu Hung-yuan required his graduate students to lay a solid foundation in quantum mechanics during their early stage of study. He would

5 At that time, the Central Committee of the Communist Party of China had already made the decision to develop atomic bombs, which required knowledge of nuclear physics and particle physics. Consequently, the government paid special attention to the development of relevant physical theory and experimentation and included them into the outline.

recommend classic works on quantum mechanics and important literature on dispersion relation for them to read. Hu Ning guided his students to shift from dispersion relation to research on group theory. Chang Tsung-sui, on the other hand, put emphasis on mathematical preciseness and led members of his lab to focus on the research of dispersion relation theory. At the time, he also devoted himself to writing the treatise *Sesan guanxi yinlun* 色散关系引论 (Introduction to dispersion relation). Although each of the three physicists had a different style of doing academic research and special areas of interest, there were frequent academic exchanges among the research groups under their leadership. In addition to writing papers in collaboration, the researchers also discussed new developments in particle physics in lectures, seminars, and so on. A research team that was active, willing to cooperate, and embracing a democratic atmosphere gradually took shape (Zhu 2015).

At that time, the development of particle physics in international academia was fairly chaotic. With the discovery of electrons, protons, neutrons, and positive electrons, as well as the proposition of pions, physicists were convinced that they had finished constructing the basic theoretical framework for the composition of matter. Nevertheless, this belief was soon challenged by the discovery of muons and a series of "strange particles." Thanks to its success in developing atomic bombs during World War II, nuclear physics attracted much attention and received sufficient funding. As a subfield of nuclear physics, the development of particle physics benefited from the ensuing progress in experimental devices and the improvement of technology. In the 1950s and 1960s, as accelerators with the energy of multi-GeV were constructed in many European countries and America, particle accelerators gradually took over the role of cosmic rays for discovering new particles. As a result, there was explosive growth in the number of new particles. Questioning whether all these particles were elementary, some physicists put forward the Fermi-Yang model, the Sakata model and the Eightfold way classification (Fermi and Yang 1949; Sakata 1956; Gell-Mann 1961; Ne'eman 1961). In 1964, M. Gell-Mann (1929–) came up with the idea that hadrons are compound particles and are made of three basic constituents (with baryon number 1/3 and electric charge e/3 and -2e/3) (Gell-Mann 1964). He called these previously unthinkable fractionally charged particles "quarks." At almost the same time, G. Zweig (1937–) and A. Petermann (1922–2011) proposed similar ideas independently (Zweig 1964; Zweig 1980; Petermann 1965).

The introduction of quarks drew the focus of physicists to the inside of hadrons in their research on the microstructure of matter. Between 1964 and 1965, experimental physicists designed all kinds of experiment in search of free quarks, but failed to find anything, which led the majority of theoretical physicists to dismiss the existence of quarks. In fact, Gell-Mann detoured when he first proposed the concept of quarks, regarding it as a mathematical symbol only. In theories dealing with strong interactions, the idea of quarks is not indispensable either. In the framework of quantum field theory, the perturbation theory can be used to deal with electromagnetic interactions, but it will fail to do so in strong interactions where the value of coupling strength is larger than 1. When quantum field theory thus lost the favor of physicists, S-matrix theory became popular, which in turn gave rise to the bootstrap theory.[6] The latter contends that there is a "democracy" among particles, that they are all equally fundamental particles and are bound states of each other. Therefore, again, the idea of quarks found no place in S-matrix theory. During that time, physicists were more interested in theories of symmetry. A. Pais (1918–2000) and his collaborators generalized the SU(4) symmetry in nuclear physics to the static SU(6) symmetry of hadrons, which not only provided a classification system of higher symmetry for hadrons, but also produced theoretical predictions of the formula for a hadron's mass, as well as the ratio of proton and neutron magnetic moments, which were relatively close to the experimental results. Later on, A. Salam (1926–1996) and his collaborators made a relativistic generalization of the SU(6) symmetry to $\widetilde{U}(12)$ symmetry. Although $\widetilde{U}(12)$ symmetry covered all the results of SU(6) symmetry, it had some other serious defaults.

Though the new concept was discounted by most physicists, there were still a few physicists who took quarks seriously. They explained that the reason why experiments failed to detect them is that the mass of a quark is so heavy that the colliders of the time did not have enough energy to produce particles of its kind. Among the most famous of these physicists was G. Morpurgo (1927–) from Italy. Morpurgo strongly believed that quarks exist and their mass is approximately 5 GeV. In 1965, he put forward the nonrelativistic quark model (NRQM),[7] provided a test method and even designed experiments to look for free quarks (Morpurgo 1965).[8] Meanwhile, Chinese particle physicists gradually shifted their attention away from dispersion relation and theories of symmetry to focus on the inner structure of hadrons. They insisted that there are physical entities inside the hadron and came up with a structure model of hadrons based on their analysis of contemporary experiments and theories. This they called the straton model.

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6 The bootstrap theory rested on two principles, both of which were more philosophical than scientific: first, that local fields were not directly measurable; second, that there were no elementary particles.

7 Morpurgo's paper was published in *Physics*. This journal was found neither in the library of the Institute of High Energy Physics nor in the National Science Library, CAS. The National Science Library was subscribed to two other journals, *Physical Review* and *Physics Letters*, which would arrive in China two weeks after they were published.

8 The email exchange on September 13, 2015 between the author and Prof. Morpurgo from the University of Genoa.

2 The influence of international politics and philosophy upon particle physics research in China

In the early years of the P. R. China, the foreign policy of "leaning on one side" (that is on the Soviet Union) increased the hostility of Western developed countries, especially the United States, and the blockade against China was tightened. In order to promote the development of theoretical and experimental nuclear physics, China successively sent over 130 scholars between 1956 to 1965 to work in the Joint Institute for Nuclear Research in Dubna, in the Soviet Union. The advanced facilities and the favorable environment of academic exchange at the Institute helped Chinese particle physicists improve their research capacities.[9] As Sino-Soviet relations worsened, the Chinese government made an effort to expand academic exchange with countries including Japan, and provided support for the 1964 Peking Symposium, so as to break the isolation imposed by the Western countries. They likewise encouraged scholars to communicate with their peers in Asia, Africa, Latin America, and Oceania. Two years later, an academic conference on a single subject, the Summer Physics Colloquium, was held in Beijing, also under the government's support.

The Japanese academy organized a group of leading scholars to attend these two meetings and thereby enhanced communication between the science communities, especially the physics communities, of China and Japan. One Japanese physicist, Shoichi Sakata (1911–1970), has played an especially important role in this relationship. He not only adopted a materialistic viewpoint and the method of dialectics in his research; he was also a left-wing social activist who followed the development of socialist countries like the Soviet Union and China with great interest (Liu, Wu, and Zhang 2012). In 1956, after attending the special session of the World Peace Council in Stockholm, Sweden, Sakata visited the Soviet Union and China upon invitation on his journey back to Japan (Anonymous 1956).[10] At that time, there was not even a diplomatic relation between the two countries. Afterwards, he did what he could to promote exchanges between Chinese and Japanese physicists and introduced new information to the Chinese physics community, thus contributing to the development of Chinese particle physics (Liu, Zhang, and Wu 2015). In 1961, he published 新素粒子観対話 (Dialogues concerning a new view of elementary particles) in Japanese, which was then translated into Russian and later by *Ziran bianzhengfa yanjiu tongxun* 自然辩证法研究通讯 (Bulletin of the studies of dialectics of nature) into Chinese. The idea that elementary particles are divisible attracted

9 The representative works of Chinese physicists when they were the Joint Institute for Nuclear Research are the discovery of $\bar{X}^-$ by Wang Kang-chang's 王淦昌 research group and Chou Kuang-chao's 周光召 research of Partial Conservation of Axial Current (PCAC).

10 According to the Chinese government, it was diplomatically meaningful to win the understanding and support of left wing intellectuals in Western countries and Japan.

Chairman Mao's attention. This had to do with his push to develop the atomic bomb as soon as possible, as well as his habitual attention to philosophical problems in physics.[11] On January 15, 1955, when he was presiding over the expanded meeting of the Secretariat of the Central Committee of the Communist Party of China in Zhongnanhai, Chairman Mao listened to the reports from geologist Li Siguang 李四光 (1889–1971), physicist Tsien San-tsiang 钱三强 (1913–1992),[12] among others, and made the decision to develop atomic bombs. During the meeting, Chairman Mao also spoke with Tsien about whether atoms and elementary particles are divisible. Having learned Tsien's explanation that elementary particles are not divisible, Mao thought it over for a while before replying, "I don't think so. From the perspective of philosophy, matter is infinitely divisible. Protons, neutrons, and electrons should also be divisible. After all, we all know that 'one divides into two, which are both united and opposite.' Now we do not have the desirable conditions to do the experiment, but in the future we will prove that they are divisible. Do you believe it? You do not believe it. Well, I do, anyway" (Tsien 1994, 271).[13] Several years later, after learning of Sakata's work to prove that matter can be divided infinitely, Mao Zedong spoke highly of it on various occasions. A few days before the Peking Symposium, Mao Zedong mentioned his approval of Lenin's statement that "everything is divisible" as well as Chuang-tzu's that "If a one-foot-long stick is cut into halves every day, the cutting will never come to an end" (一尺之棰，日取其半，萬世不竭) (Gong 2005, 124–125).[14] During the symposium, while welcoming all the participants, Mao Zedong congratulated Sakata on his achievements in particle physics research. On the following day, he specifically invited physicist Chou Pei-yuan and philosopher Yu Guangyuan 于光远 to his residence. Taking Sakata's writing as a starting point, he systematically illustrated his opinions regarding the dialectics of nature.

Mao Zedong's appreciation of Sakata's article drew unusually enthusiastic responses from Chinese academics.[15] The article was soon retranslated from Japanese

11 The Chinese Communist Party takes Marxism as its guiding ideology and advocates the unification of materialism and dialectics in terms of philosophical thoughts. Mao Zedong was not only the political leader of the Chinese Communist Party and the country, but also a thinker who had a thorough knowledge of Chinese history and traditional culture. His influence upon Chinese scientific undertakings was manifold.

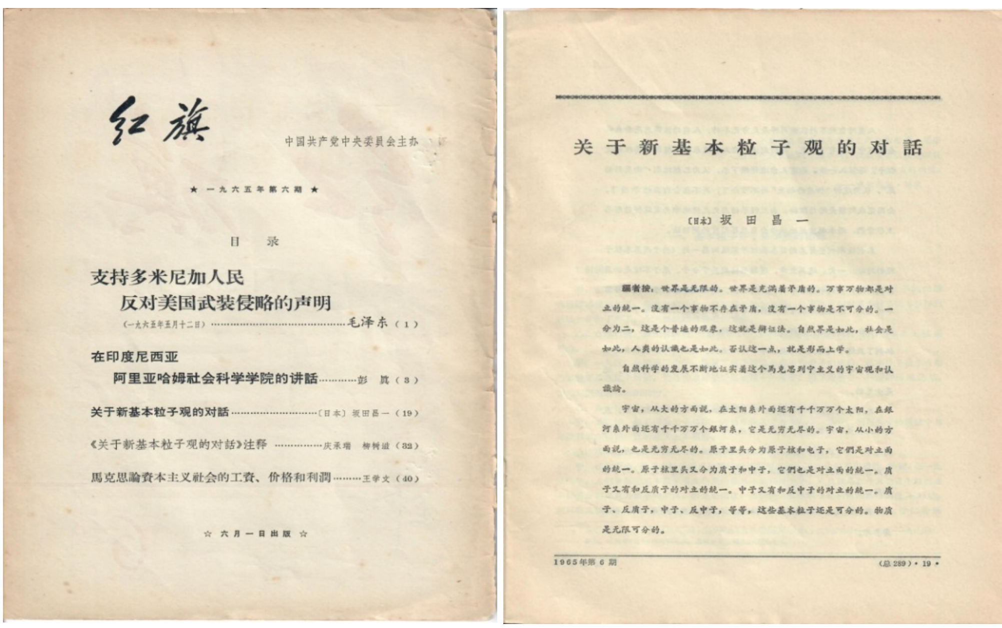
12 Tsien San-tsiang 钱三强 was regarded as "the father of China's atomic bombs." In 1937, Tsien went to the Curie Institute (The Radium Institute) at the University of Paris in France to do research on nuclear physics under the guidance of Irène Joliot-Curie (1897–1956). In 1946, Tsien and his collaborator discovered the ternary and quaternary fissions of heavy nuclei.

13 "我看不见得。从哲学的观点看来，物质是无限可分的。质子、中子、电子，也应该是可分的。一分为二，对立统一嘛！不过，现在实验条件不具备，将来会证明是可分的。你们信不信？你们不信，反正我信。"

14 The English translation is taken from Wang, Qin, and Sun 1999, 607.

15 This was because of the overwhelming influence of Mao as the political authority of China at that time.

into Chinese with annotations attached to it. Together with the "Editor's note" drafted by philosophers according to several of Mao's talks, the translation was published in *Hongqi* 红旗 (Red Flag) and *Renmin ribao* 人民日报 (People's Daily), both sponsored by the Central Committee of the Communist Party of China (Figure 1). Soon afterwards, symposiums were held in Beijing, Shanghai, Guangdong, Jiangsu, and other places, where scholars of philosophy, physics, psychology and other natural sciences talked about Sakata's article. The discussions were connected to the ongoing philosophical debate in China over the relationship between "one divides into two" (一分为二) and "two combines to be one" (合二为一) in dialectics, and gradually narrowed from how to adopt dialectical materialism in scientific research down to how to use Mao Zedong Thought as a guide for science and technology. The speeches from the symposiums above were successively published in important journals and newspapers including *Hongqi*, *Guangming ribao* 光明日报 (Guangming Daily), *Jiefang ribao* 解放日报 (Jiefang Daily), and *Ziran bianzhengfa yanjiu tongxun*, reflecting that Mao Zedong and the Central Committee of the Communist Party of China attached great importance to scientific issues related to philosophy.[16]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☆ 六月一日出版 ☆

关于新基本粒子观的对話

〔日本〕坂田昌一

编者按：世界是无限的。世界是充满着矛盾的。万事万物都是对立的統一。沒有一个事物不存在矛盾，沒有一个事物是不可分的。一分为二，这是个普遍的现象，这就是辩证法。自然界是如此，社会是如此，人类的认識也是如此。否认这一点，就是形而上学。

自然科学的发展不断地证实着这个馬克思列宁主义的宇宙观和认識論。

宇宙，从大的方面說，在太阳系外面还有千千万万个太阳，在銀河系外面还有千千万万个銀河系，它是无穷无尽的。宇宙，从小的方面說，也是无穷无尽的。原子里头分为原子核和电子，它們是对立面的統一。原子核里头又分为质子和中子，它們也是对立面的統一。质子又有和反质子的对立的統一。中子又有和反中子的对立的統一。质子、反质子，中子、反中子，等等，这些基本粒子还是可分的。物质是无限可分的。

1965年第6期　（总289）·19·

Figure 1: Sakata's "Dialogues concerning a new view of elementary particles" published in *Hongqi*, no. 6, 1965.

16 Mao Zedong was highly concerned about scientific problems that were related to philosophical issues. This had something to do with the political disagreement at that time within the party.

Sakata's work and Mao's idea that matter is infinitely divisible had a direct impact upon the research direction of Chinese particle physicists. In fact, as early as 1956, Sakata had introduced his compound model of elementary particles, that is the Sakata model, on his first visit to China, but at that time he failed to attract the attention of Chinese physicists. It was not until Mao Zedong spoke highly of Sakata's article that Chinese physicists started to do in-depth research on Sakata's model. Tzu Hung-yuan, Ho Tso-hsiu 何祚庥 and some others had been interested in philosophy and had written articles about philosophical issues in particle physics. Their articles published in 1960 called for research on dispersion relation, the symmetry of elementary particles and weak interaction (Tzu et al. 1960). During the Peking Symposium, they talked with Sakata about the relation between philosophy and dialectical materialism. Tzu Hung-yuan was active during the discussions among Chinese scientists on Sakata's article. He not only introduced Sakata's work in a meeting of hundreds of participants, but also declared in his "Jiben lizi wulixue de fazhan yu zhanwang" 基本粒子物理学的发展与展望 (The development and prospect of elementary particle physics) that the research on elementary particles should adhere to Mao Zedong Thought as its guiding ideology. The article offers a summary of the three breakthroughs in the history of physics and makes a prediction about the breakthrough to come, which "will bring to light the inner structure of elementary particles and reveal the deeper contradiction of this field of research" (Chang, Tzu, and Wang 1965).[17]

Chinese physicists had been preparing for the upcoming Summer Physics Colloquium since June 1965. The Chinese Physical Society planned to finish its academic preparation in the theory of elementary particles, the theory of nuclear structure, and the theory of solids before May of 1966. As there were a large number of scholars doing research on elementary particles, it was decided that Tzu Hung-yuan, Hu Ning, and Wang Rong 汪容 would work together to prepare a presentation covering the classification, symmetry and structure of elementary particles, the interaction between elementary particles, and the mathematical methods in theories of elementary particles. They would also try to summarize a methodology for their practice. To ensure that there would not be a shortage of hands, the China Association for Science and Technology helped to recruit some young researchers from the rural areas where they were participating in the *Siqing* 四清 (Four Cleanups) Movement (Anonymous 1966f).[18]

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17 "将要进一步发现基本粒子内部的结构，并揭露属于基本粒子领域的更深入一层的矛盾。"

18 The *Siqing* (Four Cleanups) Movement was the socialist education movement launched by the Central Committee of the CPC to re-establish socialist morality in the countryside and lasted from 1963 to 1966. It was the action to eradicate rural corruption in the areas of accounting, granary supplies, property accumulation, and work-point allocation (Spence 1990, 794).

3 The construction of the straton model and its main content

According to the experimental results available at that moment,[19] and the analogy between the theory of symmetry of particle physics and the periodic table of elements, it could be deduced that elementary particles have an internal structure. As one of the people in charge of particle physics for the Summer Physics Colloquium, Tzu Hung-yuan made a connection between Mao's thought of infinite divisibility and the theory of particle physics. He invited Dai Yuanben 戴元本 from the Institute of Mathematics in CAS to study the internal structure of elementary particles, and suggested that there are other fundamental particles than elementary particles. Later on, after their discussion, Tzu Hung-yuan, Ho Tso-hsiu, Wang Rong, Dai Yuanben, and Hsien Ting-chang 冼鼎昌 had some initial thoughts regarding the model of hadrons' structure.[20] They assumed that the elementary particle consists of sub-elementary particles, that is the particles approximately form the bases of the fundamental representation of the SU(3), SU(6) symmetry. The properties of sub-elementary particles satisfy Gell-Mann's hypothesis of quarks' properties, only that the sub-elementary particles are very heavy, reaching approximately 10 GeV.[21]

Soon afterwards, as more got involved in the discussion, the Research Group on the Theory of Elementary Particles in Peking took shape. The group was composed of young lecturers and graduate students from the Elementary Particles Research Group of the Institute of Atomic Energy, CAS, the Department of Theoretical Physics in the Institute of Mathematics in CAS, the Department of Theoretical Physics, Peking University, and the Theoretical Research Group under the Department of Modern Physics, University of Science and Technology of China.[22] Starting from September 1965, the Research Group on

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19 Four things in the experimental results implied that elementary particles have an inner structure. (1) More than 100 kinds of elementary particles discovered in the experiment were different in terms of mass, but they could be arranged in a mass spectrum. (2) SU(3), SU(6), and SU(12) symmetry theories could well predict the static properties of hadrons, despite causing disagreement with the experimental results on issues including scattering and high-resonance states decay. (3) The measurement of the electro-magnetic (or weak) form factors of nucleons through high energy electron and neutrino scattering experiments showed that a nucleon's electro charge (weak charge) was not concentrated at a geometrical point but had distribution. (4) The new particles of higher spins discovered in experiments indicated that there was orbital angular momentum within the elementary particle.

20 The author's interview of CAS member Dai Yuanben 戴元本 from the Institute of Theoretical Physics, CAS, on August 25, 2012.

21 The spin interaction can be neglected when the particle is heavy (as spin interaction is inversely proportional to the particle's mass); then the SU(3) symmetry changes into SU(6) symmetry. Considering that SU(6) symmetry successfully produces the elementary particles' spectrum, Tzu Hung-yuan and his coworkers reinforced their belief that "sub-elementary particles" are heavy.

22 In fact, at the beginning the discussion group did not have a specific name. It was named as the Research Group on the Theory of Elementary Particles in Peking during the preparation of the Summer Physics Colloquium.

the Theory of Elementary Particles in Peking organized symposiums at regular intervals (Figure 2). In the first two seminars, Tzu Hung-yuan made a presentation about the breakthroughs in modern physics, while Hu Ning made a presentation about symmetric groups and their group representation. Participants of the seminars from Peking University already had made some achievements in the theoretical research of symmetry, so each of them presented a review on topics with an individual focus, such as strong interaction, electromagnetic interaction, weak interaction, and symmetry. Hou Boyu 侯伯宇 from the Institute of Mathematics and Wang Rong from the Institute of Atomic Energy introduced works on hadron's symmetry using different kinds of symmetric groups in the international academia and parastatistics, respectively. In addition, the discussion also covered Gell-Mann's work, the similarities and differences between the quark model and the Sakata model, $\widetilde{U}(12)$ symmetry, CP violation, and so on. In the first two weeks, the Research Group on the Theory of Elementary Particles in Peking organized six seminars in succession. After that, each of the four participating organizations arranged seminars on its own, while a plenary seminar was held at least once a week, so that the scholars could communicate about their research progress and coordinate their work.

Figure 2: A seminar on the theory of elementary particles.

Tzu Hung-yuan, Ho Tso-hsiu and a few other members of the Research Group on the Theory of Elementary Particles in Peking had participated in the theoretical pre-research of China's nuclear weapons (Ho 2005). In addition, the Elementary Particles Research Group of the Institute of Atomic Energy was in charge of the study before constructing high-energy accelerators. Although some researchers of the Institute of Atomic Energy were not very familiar with the most recent achievements in particle physics, Tzu Hung-yuan made a quick decision that the group would change its direction to research on hadrons' inner structure. As it was their job to prepare presentations for the Summer Physics Colloquium within a very limited time, he put the graduate students onto a "fast track." Students were required to start research based on previous results right away, laying greater emphasis on correct results in physics than perfect mathematical forms.

The group members from Peking University had relatively strong academic backgrounds and had more chances to participate in the research. Young members from the Institute of Mathematics, on the other hand, did research according to Dai Yuanben's instructions.

In researching hadrons' inner structure, it was necessary to solve the "inner heavier than outer" bound state problem, wherein the center-of-mass motion is relativistic (that is, that the sub-elementary particles are heavier than the bound state which is composed by them).[23] In the framework of quantum field theory, there was an existing relativistic equation that describes the bound state called the Bethe-Salpeter equation (B-S equation for short). The equation itself, however, had many unsolved problems. Moreover, physicists were still suspicious of the equation's solution and its physical significance. Therefore, Tzu Hung-yuan and his coworkers decided not to study the relativistic equation of the bound state and its solution; instead, they tried to introduce directly the wave functions describing the structure of the hadrons to explain and connect experimental results. They divided the strong interaction into super-strong interaction (SU(3) symmetry) and sub-strong interaction (breaking SU(3) symmetry), the former much stronger than the latter. In the calculation of the transition matrix element, the first-order corrections to the internal structure wave functions of elementary particles caused by the sub-strong interaction were negligible. Thus, it could be assumed that 35-plet mesons (or 56-plet baryons) have the same spatial part of wave functions, and octuplets of pseudo-scalar meson and octuplets of vector mesons (or octuplets of baryons, decuplets of baryons) have the same spin part of wave functions respectively in the center-of-mass system. The electro-magnetic form factors of the nucleons showed that the momentum of the "sub-elementary particles" in the elementary particles (approximately 0.2–0.3 GeV) is much smaller than their rest mass. Assuming the "sub-elementary particles" spin was $\frac{\hbar}{2}$, as the small part of its spin wave function could be neglected in the center-of-mass system of elementary particles, then the elementary particles' spin wave function can be determined. The moving elementary particles' spin wave function can be obtained by a Lorentz transformation. The velocity of "sub-elementary particles" is small in elementary particles. When they assumed that the "sub-elementary particles" combine into bound state through instantaneous interaction, it followed that the four-dimensional internal structure wave functions of elementary particles can be described by three-dimensional wave functions. The non-relativistic approximation in hadrons can simplify the calculation of the dynamic processes of hadrons. Borrowing the concept of wave functions and the relevant computing method from nonrelativistic quantum mechanics, Tzu Hung-yuan and his coworkers proposed that the meson decay

23 The success in classifying hadrons according to SU(3) and SU(6) symmetry proved that it is feasible to make a non-relativistic approximation of the hadron's internal motion. Yet the generation process of a hadron in the accelerator is relativistic.

and transition processes could then be expressed respectively by mesons' wave functions at the origin and the overlapping integral of the initial and final meson's wave functions (The Elementary Particles Research Group of Institute of Atomic Energy, CAS 1966).[24] With all these in mind, the Research Group of the Institute of Atomic Energy constructed a relativistic model of the structure of particles with strong interactions.[25] Tzu Hung-yuan and Ho Tso-hsiu organized graduate students to calculate many processes of the electromagnetic interaction and weak interaction of hadrons, and compared the results with the existing experimental data.

Having considered that the instantaneous interaction approximation of the B-S equation was not completely relativistic, researchers from the Institute of Mathematics and Peking University worked together to propose the covariant field theoretical method for the structure model of hadrons (The Elementary Particles Research Group under the

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24 Mesons' wave function at the origin is the wave function that the distance between the "sub-elementary particle" and its antiparticle which composed the mesons is zero. As for the meson transition process, the final meson that flies out with certain momentum makes the inertial meson's spherical symmetry wave function contract along the flight direction because of the relativistic effect.

25 The wave functions of the mesons and baryons in the relativistic model of the structure of particles with strong interaction are as follows:

The wave function of the 0^- meson: $\Phi^{Ps}_{P,\zeta}(x_1, x_2) = \frac{i}{2\sqrt{2}}\sqrt{\frac{M}{E}}A(\zeta)\left(1 - \frac{i\hat{p}}{M}\right)\gamma_5\psi^{Ps}_{\zeta}(x)e^{iPX}$

The wave function of the 1^- meson: $\Phi^{V}_{P,\zeta,\lambda}(x_1, x_2) = \frac{i}{2\sqrt{2}}\sqrt{\frac{M}{E}}A(\zeta)\left(1 - \frac{i\hat{p}}{M}\right)\hat{f}^{\lambda}\psi^{V}_{\zeta}(x)e^{iPX}$

The indices Ps and V specify the pseudoscalar and the vector mesons respectively. x_1 and x_2 denote the coordinates of the sub-elementary particle and anti-sub-elementary particle. X is the coordinate of the center of mass, while x is the relative coordinate between the sub-elementary particle and anti-sub-elementary particle. P, M, and E are respectively the 4-momentum, the mass, and the energy of the meson. ζ denotes the unitary spin state, λ the state of polarization. $A(\zeta)$ is the unitary spin wave function, while $\psi(x)$ is the internal space-time wave function of the meson.

The wave function of $\frac{1}{2}^+$ baryon: $\Phi_{lm}(x_1, x_2, x_3, i, j, k, \alpha, \beta, \gamma) = \frac{1}{\sqrt{12}}\sqrt{\frac{M}{E}}\{\varepsilon_{ijk}\left[\left(1 - \frac{i\hat{p}}{M}\right)\gamma_5 C\right]_{\alpha\beta} \times U^{(\lambda)}_{\gamma}(P)\delta_{mk} + \begin{pmatrix} i & j & k \\ \alpha & \beta & \gamma \end{pmatrix}\}\psi^{\left(\frac{1}{2}\right)}_{\zeta}(x, x')e^{iPX}$

The wave function of $\frac{3}{2}^+$ baryon: $\Phi_{lmn}(x_1, x_2, x_3, I, j, k, \alpha, \beta, \gamma) = \sqrt{\frac{3}{4}}\sqrt{\frac{M}{E}}d^{ijk}_{lmn} \times \left[\left(1 - \frac{i\hat{p}}{M}\right)\gamma_\mu C\right]_{\alpha\beta}\psi^{(\lambda)}_{\gamma\mu}(P)$ $\psi^{\left(\frac{3}{2}\right)}_{\zeta}(x, x')e^{iPX}$

x_1, x_2, x_3 are the coordinates of the three sub-elementary particles. X is the coordinate of the center of mass. x, x' are the internal relative coordinates. i, j, k are unitary spin coordinates. α, β, γ are the spin coordinates. l, m, n label the unitary spin state ζ, while λ represents the polarization state of the baryon. $\begin{pmatrix} i & j & k \\ \alpha & \beta & \gamma \end{pmatrix}$ represents terms cyclic in (i, α), (j, β), (k,γ). d^{ijk}_{lmn} are a set of numbers that are completely symmetrical with respect to the upper and lower indices separately. C is the charge conjugation matrix. $U^{(\lambda)}(P)$ is the Dirac' wave function of a free, spin $\frac{1}{2}$ particle with the momentum P and the polarization λ. $\psi^{(\lambda)}_{\mu}(P)$ is the solution of the Rarita-Schwinger equation for a free spin $\frac{3}{2}$ particle with the momentum P and the polarization λ.

Department of Theoretical Physics, Peking University and the Department of Theoretical Physics in the Institute of Mathematics, CAS 1966a; ibid. 1966b). The model assumes that the particles involved in strong interactions are compound particles formed by "elementary particles." The interaction of hadrons can be explained as the interaction between "elementary particles" and other fields. Then they presented the Feynman rule of S-matrix elements,[26] which is used to describe the baryon and meson's specific physical processes. Using this rule, they also calculated many processes of the electromagnetic interaction and weak interaction of hadrons. The wave functions of the structure of baryons and mesons are required if this method is to be used in calculation. In principle, the wave function of the hadron's inner structure should be worked out from the basic motion equation of the interaction between "elementary particles," but as the form of motion equations was unknown then, based on the standard covariance and its spacetime symmetry, the researchers made a conjecture regarding the general form of the wave function of mesons and baryons. Moreover, making use of the existing quantum field bound state motion equation (e.g. B-S equation) and with certain physical considerations, the researchers also discussed the properties of wave functions.

In addition to the research results of the two areas mentioned above, members of the Research Group on the Theory of Elementary Particles in Peking also discussed the magnetic moments of hadrons, the properties of the super-strong interaction and the coupling mode among stratons, higher spin excited states, quark statistics, and other topics. During the time when the research group of the Institute of Atomic Energy, CAS, was doing the above-mentioned calculation, Dai Yuanben noticed that Morpurgo published his paper about how to use Fock Base to calculate quark-composed mesons, which was similar to his previous thoughts. The fact that some other researcher of the field was developing this method unsettled Dai. He was afraid that the Westerners would arrive there earlier, so he used the same method to calculate processes related to

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26 For example, the Feynman rules of $\omega \to \pi + \gamma,\ \pi \to \gamma\gamma$ are as follows:
The vertex of meson decay into fundamental particle pair:
$(2\pi)^4\delta^4(P - p_1 + p_2)\Gamma(p_1, p_2) \quad (0^-);\ (2\pi)^4\delta^4(P - p_1 + p_2)\Gamma_\mu(p_1, p_2) \quad (1^-)$
The vertex of fundamental particle pair merge into meson:
$(2\pi)^4\delta^4(P - p_1 + p_2)\bar{\Gamma}(p_1, p_2) \quad (0^-);\ (2\pi)^4\delta^4(P - p_1 + p_2)\bar{\Gamma}_\mu(p_1, p_2) \quad (1^-)$

External meson: $\frac{1}{\sqrt{2E}} \quad (0^-);\ \frac{e_\mu^\sigma}{\sqrt{2E}} \quad (1^-)$

Meson propagator: $\int d^4 P\Delta_f(P) = \frac{-i}{(2\pi)^4}\int \frac{d^4P}{P^2+m^2} \quad (0^-);\ \int d^4 P\Delta_{f\mu\nu}(P) = \frac{-i}{(2\pi)^4}\int \frac{\delta_{\mu\nu} + \frac{P_\mu + P_\nu}{m^2}}{P^2+m^2} d^4P \quad (1^-)$

Fundamental particle propagator: $\int d^4pS_F(p) = \int d^4 p \frac{i}{(2\pi)^4}\frac{i\hat{p}-M}{p^2+M^2}$

Fundamental particle loop: $-Sp$

Electromagnetic vertex: $-(2\pi)^4\delta^4\left(p - p' - q\right) QF_\mu(q)$

Here P is the four-dimensional momentum of meson; q is the four-dimensional momentum of photon; p_1 is the momentum of elementary particle, and $-p_2$ the momentum of anti-elementary particle; p is defined as $\frac{p_1+p_2}{2}$; Q is the charge of elementary particle.

π meson. Then Dai asked for Tzu's opinion about whether he should publish the paper. Believing that at the time, the majority of foreign physicists had not yet paid attention to the problem of hadron's inner structure, Tzu suggested that Dai should not publish his article alone, so as not to "let out the secret" (透漏风声). Instead, the Research Group on the Theory of Elementary Particles in Peking had to produce a batch of findings to present at the international conference (that is the Summer Physics Colloquium) if they were to take precedence in this field.[27] Some time later, having learned that R. H. Dalitz (1925–2006) was doing similar research and was especially interested in hadron spectrums, Tzu Hung-yuan and his colleagues decided to publish the calculation results of the Research Group on the Theory of Elementary Particles in Peking at once in Chinese on a journal which was not available to the foreign readers. With the support of Tsien San-tsiang, Director of the Institute of Atomic Energy, and Chou Pei-yuan, Vice President of Peking University, the research results were published in *Yuanzineng* (monthly) no. 3 and no. 7–8, 1966 and *Beijing daxue xuebao* (quarterly) no. 2, 1966 to form the special issues for the inner structure theory of "elementary particles" (Figure 3).

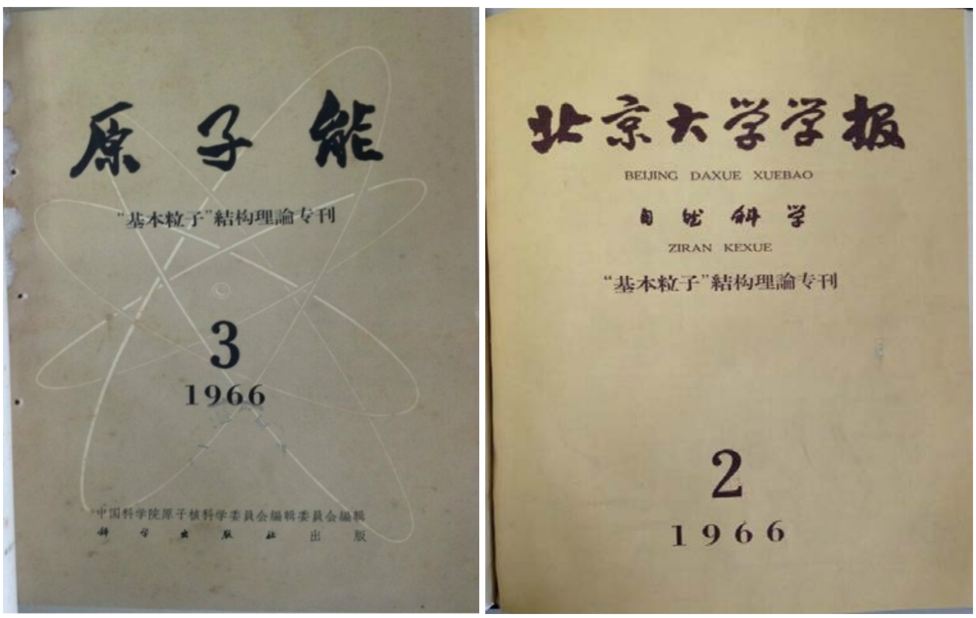

Figure 3: The special issues for the inner structure theory of "elementary particles" in *Yuanzineng* 原子能 (Atomic energy) and *Beijing daxue xuebao* 北京大学学报 (Acta Scientiarum Naturalium Universitatis Pekinensis).

Attaching great importance to the Summer Physics Colloquium, the Chinese

27 The author's interview of CAS member Dai Yuanben from the Institute of Theoretical Physics, CAS, on August 25, 2012.

government organized two preliminary meetings in late February and late May of 1966. At the time of the second preliminary meeting, the Great Proletarian Cultural Revolution ("The Cultural Revolution" for short) had just broken out. The China Association for Science and Technology stressed that the Summer Physics Colloquium would be in service of the international communist movement, the world revolution, and the international class struggle, and the meeting should be transformed to be "a pulpit for the superiority of Mao Zedong Thought and China's socialist system" (宣传毛泽东思想和中国社会主义制度优越性的讲坛) (Anonymous 1966c). Consequently, during the review process of papers, it had to be decided whether the paper reflected self-reliance to "take our own road," whether it was based upon China's reality and whether it followed the guidance of Chairman Mao's "Maodun lun" 矛盾论 (On Contradiction) and "Shijian lun" 实践论 (On Practice). The preliminary meeting selected "Jiben lizi yanjiu de fangfalun" 基本粒子研究的方法论 (The Methodology of the Research on Elementary Particles) as one of the "militant documents" (战斗性文件), suggesting that papers submitted should hold high "the red banner of Mao Zedong Thought" (毛泽东思想伟大红旗), reflect the spirit of the era of Cultural Revolution, and systematically introduce the experience and the role that the Party's leadership, the mass line, and the large-scale cooperation had played in elementary particle research. Later renamed "Zai Mao Zedong Sixiang guanghui zhaoyao xia yanjiu jiben lizi lilun" 在毛泽东思想光辉照耀下研究基本粒子理论 (Research on the Theory of Elementary Particles Carried Out under the Brilliant Illumination of Mao Zedong Thought), "Jiben lizi yanjiu de fangfalun" was one of the three key papers of the Summer Physics Colloquium (Anonymous 1966g).[28] During the preliminary meeting, Tsien San-tsiang suggested unifying the term for the component of the elementary particles. Hsien Ting-chang proposed the word "straton," or *cengzi* 层子 in Chinese (literally "particle of one of the many strata of the structure of matter"), so as to emphasize that the straton is not the most fundamental constituent of matter. Rather, it is only one of the potentially infinite strata of the inner structure of matter; the "straton" itself has an inner structure.[29]

Undeniably, the straton model was inspired by the Sakata model and the quark theory. Picking three special baryons (p, n and Λ) as fundamental particles that constitute composite particles, the Sakata model can well explain problems of mesons, but it cannot account for problems concerning baryons. The quark model regards all hadrons as equal and sees them as composite particles, whose components are at a deeper layer than hadrons. Nevertheless, Gell-Mann saw the

28 The other two papers are "Wei geming zaodeng" 为革命造灯 (Making a lamp for the revolution) and "Zai putong wuli fangmian de jiaoxue gaige" 在普通物理方面的教学改革 (Innovations in teaching general physics).

29 The author's interview of CAS member Dai Yuanben from the Institute of Theoretical Physics, CAS, on April 24, 2014.

quark as a mathematical symbol when he first put forward the model. In contrast, the straton model proposes that hadrons have inner structure and consist of stratons. Different from both the Sakata model and the quark model, the straton model contends that a collider which can provide enough energy will be able to detect the inner structure of stratons.

The Summer Physics Colloquium of the Peking Symposium was held from July 23 to July 31, 1966 (Figure 4). The colloquium received altogether seventy-two research papers and reports,[30] and 136 physicists from thirty countries and one region in Asia, Africa, Latin America and Oceania took part in it. The Chinese delegation, headed by Chou Pei-yuan, consisted of thirty-six members, all of whom had been thoroughly vetted. Even those who had made significant contributions to the research would not be able to attend the meeting if they failed to pass the vetting procedures. Some researchers who had participated in the calculation of the straton structure model failed, and were thus left out of the delegation.[31] Starting from July 24, four parallel sessions, namely physics of elementary particles, nuclear physics, solid-state physics, and physics teaching, were organized where there were paper presentations and discussions. On the morning of July 26, Wang Rong, associate research fellow from the Institute of Atomic Energy, gave his presentation titled "Research on the Theory of Elementary Particles Carried Out under the Brilliant Illumination of Mao Zedong Thought" on behalf of the Research Group on the Theory of Elementary Particles in Peking in the plenary session (Figure 5) (The Research Group on the Theory of Elementary Particle Physics in Peking 1966).[32] In his presentation, Wang Rong pointed out that the Chinese scientists had been affected by the Western metaphysical and idealist ideologies, as well as "the blind faith in the Soviet Union" (盲目信仰苏联), which had led them to detour. It was under the leadership of the Chinese Communist Party and Chairman Mao that the Research Group on the Theory of Elementary Particles in Peking broke away from the superstitious beliefs of Western "authorities" (权威) by advancing the theory of the "straton model," which best reflected the inner structure of elementary particles. Also on that morning in the plenary meeting, Professor Ogawa Shuzo from Hiroshima University in Japan gave his presentation titled "The Recent Development of the Theory of Elementary Particles—on the Sakata Model."

30 Including thirty-two on elementary particle physics, fourteen on nuclear physics, twenty on solid-state physics and other topics, and four on physics teaching.

31 For instance, Hsien Ting-chang 冼鼎昌 was told to leave the Minzu Hotel, where the preparatory work for the colloquium was going on, after he had finished writing and editing the report on the straton model both in Chinese and in English. Ho Tso-hsiu 何祚庥, to take another example, was cast as a "counterrevolutionary revisionist" during the Struggle Against the "Five Evils" and was forbidden from attending the colloquium.

32 Wang Rong's presentation was divided into several parts, including "Take Our Own Road," "The Old Must Be Destroyed Before the New Can Be Destroyed," "How Can You Catch Tiger Cubs Without Entering the Tiger's Lair?", "The First Battle," "To Rely on the Masses, on the New-born Forces," etc.

Compared to that of Wang Rong, the presentation from Ogawa Shuzo was more closely related to physics.[33] He emphasized in his presentation that their work was done collaboratively under the influence of Shoichi Sakata and Taketani Mitsuo's methodology.

Figure 4: The opening ceremony of the 1966 Summer Physics Colloquium.

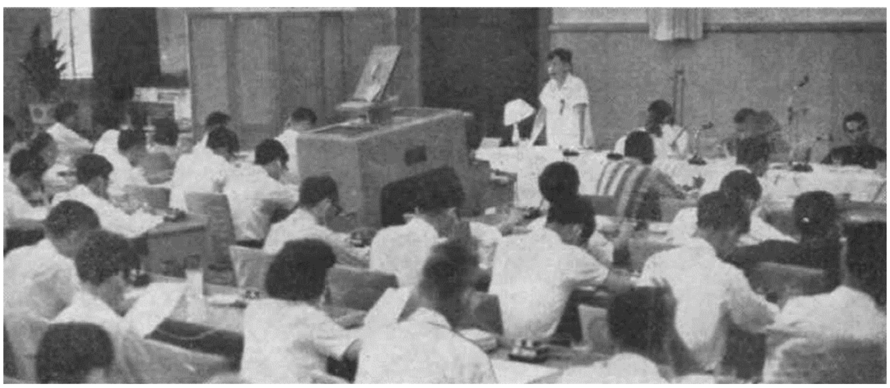

Figure 5: Wang Rong from the Institute of Atomic Energy, CAS, presented "Research on the theory of elementary particles carried out under the brilliant illumination of Mao Zedong Thought" in the plenary session on behalf of the Research Group on the Theory of Elementary Particles in Peking. Image from *People's Daily*, 8, August 2, 1966.

33 The presentation of Ogawa Shuzo is a systematic and complete summary of research development in elementary particle theory in Japan after the construction of the Sakata model. It covers the quartet scheme developed by Japanese physicists, Gell-Mann's theory of quarks, SU(6) symmetry, the Nagoya model and the most recent development of nuclear force.

Later in the group session on elementary particles, participants from different countries discussed Wang Rong's presentation and the three straton model papers presented by the Research Group on the Theory of Elementary Particles in Peking (Anonymous 1966d).[34] Chinese scientists' research method for elementary particles won the support of a majority of the colloquium's participants,[35] while there were still some researchers who held different opinions.[36] On the night of July 27, A. Salam arrived in Beijing. As a rule, the Summer Physics Colloquium would not invite Western scholars, yet as Salam was the science consultant of the Pakistani president and had made outstanding contributions to the research of particle physics, the preparatory group decided to make an exception. He was a globally well-known particle physicist, a professor of the Imperial College London, and also the science advisor to the Pakistani president. In the plenary session, he gave a speech titled "Guanyu qiangxianghu zuoyong de xin xiangfa" 关于强相互作用的新想法 (New thoughts on the strong interaction) to introduce the latest developments from Western theories about elementary particles as well as his own recent work (Figure 6). Impressed by

34 These three papers were presented by Song Xingchang 宋行长 from Peking University, Tu Tung-sheng 杜东生 and Li Bing'an 李炳安 from the Institute of Atomic Energy, CAS, respectively.

35 Prof. G. Alvial, head of the Chile delegation, said: "Previously we had no idea about how to combine politics and profession; now we know how to do that after listening to Chinese speakers' presentations" (之前不知道政治怎样同业务结合，听了中国的报告现在体会到了). He hoped to obtain all the relevant materials, so that he could do further research after returning to Chile following the Chinese method. M. K. Al-Ghita, head of the Iraq delegation, said: "Very good. You have put such a complex issue on track. I am teaching this course myself, and I am supervising graduate students' dissertations. The research on elementary particles is moving forward so fast, that while the symmetry is emphasized today, tomorrow they will be emphasizing something else. One book that the students read say this, but some journal would say something different. For twenty years, we did not even have a fixed definition for the elementary particle. Now that Wang Rong's presentation has made it clear about the several requirements of the wave function, we now know what an elementary particle is for sure. I believe you have found the right path" (非常好。把这样复杂的问题引上了正确的道路。我自己是教这门课的，也带研究生作学位论文，但是基本粒子发展这样快，今天强调对称性，明天又强调别的；让学生看这本书这样讲，那本杂志又那样讲。二十年来，连基本粒子怎样定义都没有一个说法。现在汪容的报告把波函数的几个要求弄清楚，基本粒子是什么就明确了。我相信，你们找到了正确的道路).

36 Fortunato Donon, head of the Argentina delegation, said, "Then this thing of dividing matter would be endless!"(物质这样分下去，永远没完了！). A representative called Ricardo S. Sussmann commented that after listening to Chinese speakers' presentation, he still had no idea of how Mao Zedong Thought had guided particular scientific research. M. Baghdadi, head of the Syria delegation, said, "Here in your country, we see quotations from Mao Zedong everywhere, while hardly anything from Marx can be spotted. You have deified Chairman Mao, as if he was someone like Allah in Islam. Of course he is great, as he has liberated the whole country and changed the way that China looks like. I am not opposed to this; I agree. Nevertheless, Chairman Mao is still a human being" (你们到处都是毛泽东语录，没有看见马克思一句话。你们把毛主席神话了，象穆斯林教的真主一样。当然毛主席很伟大，解放全中国，改变中国面貌。这我不反对，我也十分拥护。但毛主席也是一个人).

Chinese physicists' research concerning the inner structure of elementary particles,[37] Salam expressed his hope that Chinese elementary particles theory would make significant progress when the Peking Symposium of 1968 was held (Anonymous 1966e).

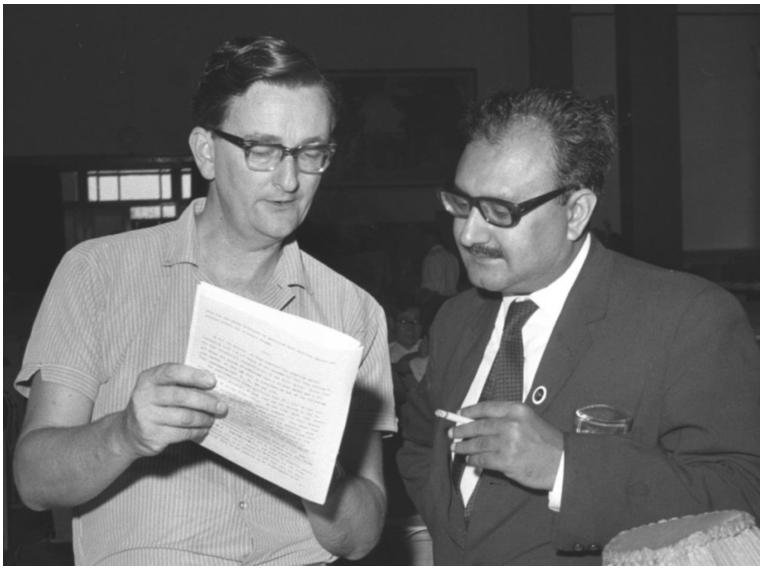

Figure 6: Salam (right) talking with a representative attending the 1966 Summer Physics Colloquium.

During the Summer Physics Colloquium, participants of foreign countries hoped to meet Chairman Mao. On July 31, 1966, in the afternoon and in the evening, Liu Shaoqi 刘少奇 and Mao Zedong received participants of the colloquium.

Originally, the calculation results of the theory of stratons' inner structure were to be published in English after the Summer Physics Colloquium. However, due to the Cultural Revolution, most scientific research in China was suspended and academic journals ceased publication. The plan was thus disrupted. While during the Cultural Revolution the revolutionary struggles[38] were placed above daily work, physicists of the Institute of Atomic Energy, CAS, were still allowed to do some research, thanks to the fact that the research tasks assigned to them were related to the development of

37 In his presentation, Salam mentioned that he started to explore the weak decay of hadrons with the presumption that elementary particles have inner structure since the beginning of 1966. Chinese physicists had finished major presentations on the theory of straton model when Salam arrived at Beijing. The author's speculation is that Salam learned about the straton model theory from the conference papers and his discussion with Chinese physicists.

38 During the early years of the Cultural Revolution, governmental institutions, schools, research institutes, factories, and agricultural production teams all over the country organized "struggle sessions" targeting those who held views diverging from Mao Zedong's, and daily work was simply put aside in such chaos.

nuclear weapons. The work of the Institute of Mathematics, however, was regarded as useless and "was stopped so that workers could carry out revolution" (停产闹革命). For a time, it was even planned that the institute would be replaced by a national liaison office.[39] The research conducted at Peking University was almost suspended as well. Nevertheless, during that time there were still some leaders who cared about the research of elementary particles. In May 1967, the State Scientific and Technological Commission organized the Forum of Fundamental Theory Research in Beijing. Marshal Nie Rongzhen 聂荣臻, the vice premier of the State Council who was in charge of work related to science and technology, pointed out during the meeting that "we had a paper on elementary particles last year during the colloquium. If we are to present some results next year, we have only one year left, and that will be in a hurry. We need to focus on a topic. We left a mark last year and that should not be a single effort. We must be well prepared for the symposium next year" (Nie 1999, 606).[40] Unfortunately, the 1968 Peking Symposium was called off due to the vigorous Cultural Revolution. Physicist Y. H. Woo, the vice president of the Chinese Academy of Sciences, attached great importance to the research of elementary particle theory. On January 23, 1972, he wrote to Liu Xiyao 刘西尧, the liaison of Premier Zhou Enlai at the Chinese Academy of Sciences, expressing his hope that research on the theory of hadrons' inner structure could receive priority and achieve new results soon afterwards. He also suggested sending delegates to an international conference on high energy physics to present both the old and new results of theoretical research on hadrons' structure, so as to reflect the new look of the scientific research in China after the beginning of the Cultural Revolution (Woo 2007, 424–425). His proposal was approved by Liu Xiyao on the following day. Premier Zhou Enlai was also concerned about the development of high energy physics. In August, 1972, 18 particle physicists including Chang Wen-yu 张文裕, Tzu Hung-yuan, Wang Rong, and Ho Tso-hsiu wrote a joint letter to Premier Zhou Enlai, calling for attention to the research of high energy physics. Zhou Enlai made it clear in his reply that "this should not be postponed anymore. The Chinese Academy of Sciences must on the one hand spare no effort to make progress in basic science and theoretical research, and on the other hand combine the theoretical research with scientific experiments. The research on high energy physics should be one of the focusing points" (Zhu 1977).[41]

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39 The author's interview of Zhu Zhongyuan 朱重远, research fellow from the Institute of Theoretical Physics, CAS, on January 8, 2014.

40 "基本粒子，去年在北京物理讨论会上有一篇论文，明年如果搞，只一年的时间，很仓促呀！应该有一个题目。去年放了一炮，第二炮就不响了，怎么行？我们要在此基础上好好准备明年的科学讨论会。"

41 "这件事不能再延迟了，科学院必须把基础科学和理论研究抓起来，同时又要把理论研究和科学实验结合起来。高能物理研究应该成为要抓的主要项目之一。"

In contrast to research in other thematic groups, especially those studying basic science which came to a stop in the Cultural Revolution, there was still a little progress concerning the straton model during these years, thanks to the fact that some leaders of the Central Committee of the Chinese Communist Party laid great stress on elementary particle research. As academic journals including *Wuli* 物理 (Physics), *Kexue tongbao* 科学通报 (Chinese Science Bulletin), and *Wuli xuebao* 物理学报 (Acta Physica Sinica) resumed their publication, research results got published. The theoretical group of the Institute of Physics, CAS, did research in the framework of the straton model and compared it to the non-relativistic quark model. Ho Tso-hsiu and Huang Tao 黄涛 from the Institute of Atomic Energy, CAS, formulated the composite quantized field theory. Li Bing'an 李炳安 discussed wave functions of hadrons and 1/2+ baryons' electro-magnetic properties and △(1236)'s photoproduction and electro-production phenomenon. Zhu Zhongyuan 朱重远 from the Institute of Mathematics, CAS, used the straton model to study the common physical mechanism of $\pi^0 \rightarrow 2\gamma$ decay and estimated these mechanisms' contribution when its mass is big. Li Xiaoyuan 李小源 from Peking University advanced a new potential scheme of the straton's inner structure. Physicists from the University of Science and Technology of China, Sun Yat-sen University, Inner Mongolia University, and Shandong University also did relevant research in the framework of the straton structure model. Meanwhile, in terms of experimentation, Chinese experimental physicists were looking for free stratons. In June 1972, at the cosmic ray observation station in Luoxueshan 落雪山, Yunnan Province, an ultra-high energy event was discovered with the help of a big magnetic cloud chamber. It was thought that this event might prove the existence of free stratons, attracting much attention from Chinese physicists and Zhou Enlai. Unfortunately, the event was not confirmed by further experimental results.

At the time when the research of elementary particles in China came to a halt, the international particle physics circle made significant progress both in theories and in experiments. In the late 1960s, S. Weinberg (1933–), Salam, and S. L. Glashow (1932–) introduced the SU(2)×U(1) gauge group and applied the spontaneous symmetry breaking mechanism to develop the electro-weak theory (Glashow 1961; Weinberg 1967; Salam 1968). At approximately the same time, the large angle scattering phenomenon of electrons by nuclei was discovered in a deep-inelastic electron-proton scattering experiment of the Stanford Linear Accelerator Center (SLAC). This phenomenon was explained by R. Feynman (1918–1988) and J. Bjorken (1934–) as protons and neutrons consisting of partons. It was then natural for physicists to connect partons with quarks. H. Fritzsch (1943–) and Gell-Mann introduced the concept of "color" to solve the statistical problem of quarks, and developed the quantum chromodynamics (QCD) with the gauge symmetry group SU(3), which is a kind of Yang-Mills gauge theory, to describe the strong interaction (Fritzsch and Gell-Mann 1972; Fritzsch, Gell-Mann, and

Leutwyler 1973). After that, D. Gross (1941–) et al. found the asymptotic freedom property of QCD, which made it possible to utilize the perturbation theory to deal with strong interaction (Gross and Wilczek 1973; Politzer 1973). The discovery of Charm quarks, bottom quarks, "three-jet events," anti-quarks and gluon-jets convinced most particle physicists that QCD was the correct theory to describe the strong interaction, namely how hadrons are composed by two or three quarks (and innumerable quark-antiquark pairs) through colored gluons. Later on, the quantum gauge field theory governed by the symmetry group U(1)×SU(2)×SU(3) with the spontaneous symmetry breaking that is referred to as the standard model (SM) in elementary particle physics was established.

After the end of the Cultural Revolution in 1976, as scientific research regained attention in China, the theoretical research of particle physics restarted gradually. The popular science journal *Gaoneng wuli* 高能物理 (High energy physics) and academic journal *Gaoneng wuli yu hewuli* 高能物理与核物理 (High Energy Physics and Nuclear Physics) were started in succession.[42] Moreover, Tsien San-tsiang, Chou Pei-yuan, and some of their colleagues organized several conferences on particle physics. In 1977, there was the Beijing High Energy Physics Planning Conference, during which there was a symposium on the theory of particle physics, and the Huangshan symposium on the theory of particle physics. The following August, the first annual meeting of the Chinese Physical Society since the Cultural Revolution was held in Lushan, Jiangxi Province. Chou Pei-yuan said in the opening speech that,

> I am especially concerned about research on elementary particles, because this is the forefront of physics as a whole. . . . During the seventeen years—which is a short period of time—before the Cultural Revolution, our country made two great contributions to theoretical physics. One is that we worked out the theory to produce atomic bombs and hydrogen bombs completely on our own, and the other is that we proposed the straton model to describe hadron's inner structure. . . . In 1966, we proposed the straton model and gave a presentation during the Summer Physics Colloquium in Beijing. That had won the approval of the international physics community. While we were all happy about it, some of our colleagues became conceited, as if the problems of elementary particles had already been settled. They considered themselves materialists, while labelling their peers as idealists. This not only hurt the solidarity among researchers at home and abroad, but also impeded our own progress. Never ever be conceited when you have a little achievement; be a theoretical physics researcher who is both politically

42 The early issues of *Gaoneng wuli* (quarterly, later renamed as *Xiandai wuli zhishi* 现代物理知识 [Modern Physics]) were mainly introducing the theory of straton model. The first issue of *Gaoneng wuli yu hewuli* includes a review titled "Jianchi zhengque de fangxiang nuli yongpan gaofeng huigu cengzi moxing shiyinian" 坚持正确的方向努力勇攀高峰——回顾层子模型十一年 (Sticking to the right direction to conquer the high peak: A review of the eleven years since the straton model was constructed).

sound and professionally competent. (Chou 1978a)[43]

Additionally, he suggested that physicists should pay attention to the straton's motion equation. A symposium on elementary particles was held during the meeting in Lushan, which summarized progress made both at home and abroad in the theories and experiments of hadron structure and looked ahead to the direction of future research.

The first conference on elementary particle physics attended by physicists of Chinese origin working abroad was held from January 5 to January 12 in Conghua, Guangdong Province, and was regarded as "an overall review of the recovery of particle physics research in China" (粒子物理理论研究在中国恢复工作的一个大检阅) (Tzu 1980a).[44] Eminent physicists of Chinese origin including T. D. Lee and C. N. Yang were all present. During the conference, Tzu Hung-yuan gave a report titled "Reminiscences of the Straton Model" (Figure 7) (Tzu 1980b, 4). In his report, Tzu systematically summarized the calculation results of the straton model, and for the first time provided the names of the thirty-nine people who took part in the research work. Tzu Hung-yuan's report drew wide attention from the conference participants. T. D. Lee described this report as "very important, with historically significant reminiscences" (很重要、是具有历史意义的回忆) (Anonymous 1980). Bambi Hu, assistant professor of University of Houston, commented: "The 'straton model' was a very meaningful work at the time. . . . In the 1960s, the Western theories of particle physics were in a mess. There was a tendency to only pay attention to the mathematical form while ignoring physical knowledge. At such a time, Chinese researchers emphasized that the elementary particles have inner structures, spread the Sakata model and later put forward the straton model, reemphasizing the physical thinking. This indeed has guiding significance" (ibid.).[45] Moreover, he believed that it was correct to use the philosophical idea that matter is infinitely divisible to guide particle physics research. Bei-Lok Hu from Lyman Laboratory of Physics at Harvard University stated that "We

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43 "基本粒子的研究是我很关心的事，因为基本粒子的研究是站在整个物理学的最前线。……在"文化大革命"前短短十七年中，我国理论物理有两大贡献：一是完全独立地掌握了制造原子弹和氢弹的理论；二是提出了强子结构的层子模型。……1966 年我们搞了层子模型，在北京物理讨论会上做了报告，国际上认为有水平，我们大家都高兴。但有些同志就骄傲自满了，好像基本粒子问题已经解决了。把自己看成唯物主义，而给别人扣上唯心主义，既影响了内外的团结，又妨碍了自己的进步。我们做了一点成绩，千万不要骄傲自满，要真正做个又红又专的理论物理工作者。"

44 Altogether seventy-eight papers were presented during the conference (forty-four from home, and thirty-four from abroad) and 148 representatives (ninety-seven from home, and fifty-one from abroad) were present. The conference mainly introduced the latest development in the theoretical research of particle physics in the international academia, including fields like gauge field theory, quantum chromodynamics (QCD), phenomenology theory of strong interactions, gravitational theory, grand unified theory, point particle, etc.

45 "'层子模型'在当时确实是一个很有意义的工作。……六十年代西方在粒子物理方面的思想比较乱，有忽视物理内容，只注重数学形式的倾向。在这个时候中国强调基本粒子还有结构，宣传坂田模型，后来又提出层子模型，重新强调要有物理思想，这确实是有指导意义的。"

should not equate the straton model to the quark model. When it was first proposed, quark was not regarded as one stratum of the structure of matter; rather, it was only for the mathematical treatment. Only later did we see quarks as particles that are more elementary than the elementary particles. To be more precise, it was after the straton model had been put forward. So in that sense, the straton model goes one step further than the quark scheme" (Anonymous 1980).[46] During the discussion, some participants reported that it was very difficult to obtain reference materials concerning the work on the straton model when they were abroad, and asked for the original papers related to the straton model. T. D. Lee offered the suggestion of sorting out the 1966 papers on straton model and publishing them abroad in English, which won universal approval among the conference participants. Unfortunately, so far, the works on the straton model have not yet been edited and published in English. After the Guangzhou Conference, representatives from China suggested summarizing the work on the straton model from a relatively objective point of view, hence Tzu Hung-yuan, Song Xingchang 宋行长 and Zhu Zhongyuan worked in collaboration to write "Cengzi moxing de huigu yu zhanwang" 层子模型的回顾与展望 (Reflection and outlook of the straton model) (Tzu, Song, and Zhu 1980).[47]

Figure 7: Tzu Hung-yuan presenting "Reminiscences of the Straton Model" in the Guangzhou Conference on Theoretical Particle Physics. Image from the *Photomall* website, Xinhua Agency.

46 "不能将层子模型完全等同于夸克模型，夸克刚提出来时并不是作为物质的一个层次，仅仅是数学上的处理方法。把夸克作为比基本粒子更深一层的粒子是后来的事情，具体说是在层子模型提出来之后，所以层子模型比夸克模型进了一步。"

47 After Tzu Hung-yuan first "set the tone" (定了调子) for the article, Song Xingchang and Zhu Zhongyuan wrote the early draft, which was finalized through discussions of the three. Song believed that the article "was historically reliable and reflected what we had actually done, while political slogans inevitably slipped in" (本着对得起历史，对得起实际工作，但文中不免有些口号). The author's interview of Prof. Song Xingchang from Peking University, on January 16, 2014.

In order to learn about the most recent progress in studies of hadron structure and the phenomenological theory of strong interactions, the Conference on Hadron Structure was held in Wuhan in October 1980. During the conference, Hu Ning expressed his thoughts on the straton model,[48] stressing that those who study physics should on the one hand have opinions and beliefs, while on the other hand be brave enough to change their opinions when faced with facts. He suggested paying attention to the QCD theory, especially to the deep-inelastic problem (Hu 1980). In his closing address, Tzu Hung-yuan viewed the Guangzhou Conference as the end of a phase in the development of Chinese particle physics, and the Wuhan Conference as the start of a new phase (Tzu 1980a). With his prediction that the major future development of particle physics would occur in areas including strong interactions, theories of hadron structure and grand unified theory, Tzu Hung-yuan suggested paying more attention to research on emerging topics including straton spectrum, lepton spectrum, straton structure, and lepton structure. He claimed that this field of research was first opened up by Chinese scholars, and should not be handed over to someone else. Later, as the physics community accepted the QCD theory as the proper one to describe strong interactions, the theory of straton model gradually lost its predominance in the particle physics circle in China. Since then, the research interests of Chinese particle physicists have shifted to directions such as gauge field theory, QCD, phenomenological theory of strong interactions, gravitational theory, grand unified theory, etc. In 1982, the straton model won the Second Prize of National Natural Science Award, the main winners being Tzu Hung-yuan, Hu Ning, Ho Tso-hsiu, and Dai Yuanben.

4 Foreign physicists' comments on the straton model

During the Summer Physics Colloquium, Japanese representatives paid great attention to the research on the straton model. In the invitation telegram sent to Shoichi Sakata and his colleagues in early July 1966, Chou Pei-yuan mentioned the research on the inner structure of elementary particles that was in progress in China, saying that "it contains the positive side of the symmetry theory which prevails in Western countries and overcomes its difficulties, thereby obtaining very interesting results" (Anonymous 1973).[49] With this in mind, Sakata predicted before the colloquium that "Chinese scientists are going to deliver some very ambitious results on elementary particles"

48 Hu Ning said that there are three reasons why he appreciated the work of hadron model: (1) group theory (especially SU(3) symmetry which successfully classified the hadrons); (2) deep inelastic scattering processes unexpectedly give the structure function, and one of the most important points is that the interaction between photon and straton can be seen as elastic scattering; (3) mass spectrum (for mesons it is not obvious; but for baryons, the Regge trajectories are completely parallel lines).

49 "其中包含在欧美流行的对称性理论的积极的一面，同时还消除了其中存在的困难，获得了很有趣的成果。"

(ibid.).[50] The Japanese delegation had planned to give a lecture during the colloquium, but they packed up all the handouts upon hearing the report on the straton model. Professor S. Hayakawa wrote to Sakata, who stayed in Japan to attend a conference in Kyoto, "some of our newspapers or weekly magazines had slighted the research of Chinese scientists as 'hollow,' but that is by no means the truth. Their work is substantial and is at a very high level" (Anonymous 1966b).[51] He believed that the work of the straton model was more detail-oriented and systematic than that of the Japanese particle physicists, and that the Chinese young researchers were working in the spirit of the contemporaries of Sinitiro Tomonaga. Nogamt Mokichiro, head of the Japanese delegation, said when he met Tsien San-tsiang,

> Japan did a lot in the past, but we failed to explore deeper. Now we can see that you are taking the lead. . . . Japanese young researchers of theoretical physics have two shortcomings. One is that they have a blind faith in American science. They believe that anything that has been published in American physics journals will work out, and is worth doing. They seldom create on their own. The other is that they believe in experiments only and dare not to think about something that has not been proved by experiments. The direction of thinking and the research method of Chinese researchers are exactly what are lacking in young Japanese scholars. (Anonymous 1966a)[52]

Ogawa Shuzo, secretary of the Japanese delegation, commented that "the Chinese physicists are working in a correct direction to develop the straton model and they have taken one step further into the structure of matter. Japan wanted to make that step as early as in 1960, but we never did it. Now that China has made it, we need to have a thorough discussion so that we can make greater progress in this field" (ibid.).[53] When the Summer Physics Colloquium ended, the Japan delegation had a three-day meeting with Chinese particle physicists to exchange information and discuss the straton model in detail. During the meeting, some Japanese delegates disagreed with Chinese scholars who laid stress on Mao Zedong Thought and held it as the guiding ideology of elementary particle research, arguing that Sakata had made contributions to the straton model as well. After returning to Japan, the Japanese delegates provided a detailed description of the Summer Physics Colloquium, as well as specific information about the straton model, to their colleagues.

The Sino-American relationship began to thaw in the late 1960s after many years of

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50 “中国科学家关于基本粒子论要发表有雄心的成果。”

51 “中国的研究工作绝不是日本的一部分报纸、周刊杂志所中伤的那样的没有内容的工作，而是内容很充实的高水平的研究。”

52 “日本过去做了不少工作，但是没有钻下去，这次看来你们走在前面了。…… 日本理论物理学青年工作者有两个毛病：一是迷信美国，凡是美国物理杂志有的，就认为行、就作，自己独创很少。二是只信实验，实验没有证明的就不敢去想。中国的工作方向、方法正是日本青年学者所没有的。”

53 “中国层子模型方向对头，是向更深一层迈进了一步，日本在 1960 年时就想迈一步，但一直没有迈下去。这回中国迈进了，我们要很好地讨论，使得这方面工作有更大的进展。”

antagonism. The United States eased restrictions on its citizens' outbound trips to China and on trade between the two countries. Diplomatic contact also resumed. In 1971, C. N. Yang seized the chance to apply for a visit to China. He successively gave three academic reports in Shanghai and Beijing. Before his presentation in Beijing, whose title was "Jiben lizi de kongjian jiegou" 基本粒子的空间结构 (The spatial structure of elementary particles), the reception commission in Beijing organized some physicists to learn about the progress of the international particle physics circle, investigate Yang's recent work, and make a summary of the straton model theory (Anonymous 1972a). Li Bing'an from the Institute of Atomic Energy introduced the work on the straton model after C. N. Yang finished his report. Yang, however, had a different opinion regarding the inner structure of elementary particles. According to him, while elementary particles do have spatial structure, they are not composed of particles that are more elementary. In a later seminar, C. N. Yang suggested that as there were not many researchers in the field when the model was first proposed, Chinese physicists should write a book on the straton model to facilitate discussion, which would also help them to organize their own thoughts (Anonymous 1972c). In fact, Yang was not clear about the specific content of the straton model when he returned to China; it was in *New York Times* that he first learned about the model. Chou Pei-yuan and Chang Wen-yu suggested offering Yang copies of the three papers that had been presented during the 1966 Summer Physics Colloquium, so that he could have a thorough understanding of the model and have something to refer to when he introduced the model to his audience after he returned to the US. Chou and Chang believed that "this is actually helping us to disseminate Mao Zedong Thought" (这实际上也是为我们在基本粒子的研究中宣传毛泽东思想) (Anonymous 1972a).

After he returned to the US, C. N. Yang regarded the Chinese high-energy physics circle before the Cultural Revolution as "very active" in an interview with G. B. Lubkin, senior editor of *Physics Today* (Lubkin 1971). On July 17, 1973, Mao Zedong received Yang in his study in Zhongnanhai. During the meeting, Mao Zedong once again emphasized his idea that matter is infinitely divisible. He consulted Yang about the recent developments of Copenhagen School and whether photons are divisible. Yang's answer to the latter was that it was still unsettled. Mao Zedong said that he personally believed that matter is infinitely divisible. If there was a certain point beyond which matter was no longer divisible, scientists would have nothing to do ten thousand years later.[54] In addition, Mao mentioned Gongsun Long 公孙龙, and Hui Shi 惠施, as well as proverbs including "If a one-foot-long stick is cut into halves every day, the cutting will never come to an end" (一尺之棰，日取其半，萬世不竭), "the shadow of a flying bird can be said to be static" (飛鳥之影未嘗動也),[55] "the center of the world, I can say it is to the north of the

54 During this meeting, Mao asked how Sakata was doing. Chou Pei-yuan, who was also there, answered that Sakata had passed away in 1970.
55 The English translation is taken from Wang, Qin, and Sun 1999, 605.

state of Yan or to the south of the state of Yue" (天下之中央，燕之北，越之南),[56] and "A white horse is not a horse" (白馬非馬) among others. As for whether particles are divisible, Yang answered that the international academia has two opinions. One is that the elementary particles do have an inner structure but that it is unobservable, and the other is that the inner structure could be observed, though scientists had not yet managed to do so. Then Chou Pei-yuan changed the subject to the law of parity non-conservation. C. N. Yang explained that in simple terms, parity conservation is left-right symmetry. Inside the nucleus, parity is conserved in strong interaction and electromagnetic interaction, but it is violated in weak interaction. Mao asked, "So the parity can be both conserved and violated. Is that true?" He said that his specialty was politics and was not familiar with science. He praised C. N. Yang for making contributions to the world (Chou 1978b).

Salam was still concerned about the development of the straton model as well. After the Summer Physics Colloquium, he attended the thirteenth International Conference on High Energy Physics held in Berkeley, USA. Ho Tso-hsiu once mentioned in his writing that Salam was promoting the straton model in the conference, but the author did not find any relevant record in the conference proceedings (Ho 2005). Early in September 1972, Salam visited China again and gave a presentation which involved the cutting edge theoretical problems in particle physics and his recent works. Even some important research findings that had not been published were included in his report.[57] Salam's presentation was well received among the audience. Later on, he attended a symposium together with more than twenty physicists including Chang Wen-yu, Wang Rong, Ho Tso-hsiu, and Dai Yuanben. Salam answered his Chinese peers' academic questions in detail and introduced them to recent trends in the international research community, so that Chinese physicists could learn about foreign researchers' work during the Cultural Revolution. In his discussion with Chinese researchers, Salam repeatedly commended the work on the straton model and asked about the recent development in related research.[58] He stated at the beginning of his report that:

> For me, every time when I arrive in Beijing, I feel as if I arrived at home. When I was here in 1965, I did not get a chance to talk about my work. In 1966, I was here again. I learnt from the Summer Physics Colloquium that you had made many achievements, and that they had something to do with my work. You have spent great efforts on that, and I would love to learn about it. . . . As far as I know, in 1966, what physicists in Beijing were doing was studying the B-S equation of the bound states that were composed of stratons and trying to figure out the relation between dynamics and symmetry. I think it was very in-depth research at that time, and I am very eager to know if there is any further

56 The English translation is taken from Wang, Qin, and Sun 1999, 605.

57 Salam's presentation was very detailed. As he did not finish in the morning, he spoke for another hour in the afternoon.

58 To fit in with the situation in China, Salam used "straton" rather than "quark" in his presentation and in the symposium.

development since then. (Anonymous 1972b)[59]

Glashow and Weinberg, the two other physicists who shared the 1979 Nobel Physics Prize with Salam, took interest in the straton model as well.[60]

5 Conclusion

The straton model put forward by Chinese physicists in the 1960s fit well into an emerging trend of particle physics at that time. When the dominant academic view held hadrons to be point particles, Chinese physicists directed their thoughts towards the future of particle physics. In their theoretical exploration of hadrons' inner structure, starting from the idea that there are physical entities inside hadrons and borrowing methods from nuclear physics and quantum field theory, they chose not to tackle the quantum field equation of bound states; rather, they introduced concepts including the wave function of hadrons' inner structure and the overlapping integral of straton's wave functions, and offered a set of approximation methods to work out the S-matrix element. Some of their theoretical calculation results obtained from the systematic research of hadrons' electromagnetic and weak decay processes are consistent with contemporary experimental results elsewhere and were cutting-edge for that moment in theoretical research. If things had gone according to plan, after the Summer Physics Colloquium, the Research Group on the Theory of Elementary Particles in Peking would have proceeded by approaching some more important problems, like the straton's mass and the forms of

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59 "对我来说，每次到了北京就像回到自己家里一样。1965 年我到北京来，没有机会谈谈我的工作，1966年我又来到了中国，在物理讨论会上我知道你们做了很多工作，而且你们的工作和我的工作有一定的关系。你们做了很多工作，我很想了解你们的工作。……66年北京物理学者所进行的工作，据我所知，是研究层子之间束缚态 B-S 方程，试图得出动力学和对称性之间的关系。我认为在当时这是一个很深入的工作，我很想知道，在此以后有没有进一步的发展。"

60 In August 1977, Glashow mentioned in his presentation in the Seventh Hawaii Topical Conference in Particle Physics, held in University of Hawaii at Manoa, that,

"Today, we are left with quarks and leptons as candidates for truly elementary particles. However, experiment has already revealed the existence of five kinds of quarks and five kinds of leptons. More are probably on their way. How many must we find before someone detects a sign of order, a clue to the existence of further structure not yet imagined?

Is there another layer of the onion? Is there a common fundamental constituent of both quarks and leptons? Such a notion has been championed by many Chinese physicists. I would propose that these hypothetical building blocks of all matter be called 'MAONS,' to honor the late Chairman Mao who insisted upon the underlying unity of Nature." (Glashow 1978)

In his popular science book *The First Three Minutes*: *A Modern View of the Origin of the Universe*, Weinberg recorded that "the small group of theoretical physicists in Peking has long favored a version of the quark theory, but they call them 'stratons' instead of quarks because these particles represent a deeper stratum of reality than the ordinary hadrons" (Weinberg 1993, 140). During his visit of China in 1978, Weinberg gave three presentations centering on the "Weinberg-Salam model." He also had discussions with Chinese physicists who were participating in the research of the straton model.

strong interactions. Unfortunately, because of the Cultural Revolution, their research did not go much further. Meanwhile, however, a few physicists in international academia were following this direction in their research and eventually made their own breakthroughs, which led to the establishment of quantum chromodynamics (QCD).

During the 1960s and 1970s, Chinese physicists were not only dedicated to the pursuit of truth; they managed to address the political, ideological and diplomatic concerns of the time as well. Materialistic dialectics and Mao Zedong's idea that matter is infinitely divisible had a significant influence upon Chinese research of particle physics. The academic preparation for the 1966 Summer Physics Colloquium directly led to the birth of the straton model. Adapting to the political situation of the time, Chinese physicists accepted the philosophical thought that was promoted by the government, combined it with their research on particle physics and put forward the theoretical model of their own. To some extent, the straton model, which was held up as an example of successful scientific exploration under the guidance of Mao Zedong Thought, was constructed under the influence of the interaction between science and politics. What is worth reflecting on is that the hostility between China and developed countries, as well as the academic environment in China at that time, made it very difficult for Chinese physicists to learn about recent developments from the international theoretical physics circle. Moreover, Chinese physicists at that time usually chose not to publish their latest findings in foreign languages unless they systematically studied one topic. As a consequence, the straton model had barely any influence on the development of particle physics. Other scientific fields in China faced similar problems at the time.

According to the results of high-energy physics experiments, the inner structure of quarks have not been detected yet within the scale of 10^{-15} cm. It is therefore difficult to prove the philosophical thought that matter is infinitely divisible. Even so, a number of young particle physicists grew into maturity in the process of building the straton model. Full of vigor and vitality, these young researchers who participated in the calculation of the model had the courage both to accept and to propose new ideas. The construction of the model improved their research competence. In the new era of reform and opening up, these young scholars and their younger peers integrated into the international particle physics circle and achieved good results both in theoretical and experimental research. As far as theory goes, they have made contributions to the research of the global properties of quantum field theory, gauge field theory and other fields. As for experimentation, they contributed to the establishment of the Beijing Electron Positron Collider (BEPC), which accurately measures the mass of τ-lepton, and the Daya Bay Neutrino Experiment, which discovered a new type of oscillation of neutrinos. In certain ways, the research of particle physics was the epitome of the development of basic science in the P. R. China during the 1960s.

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