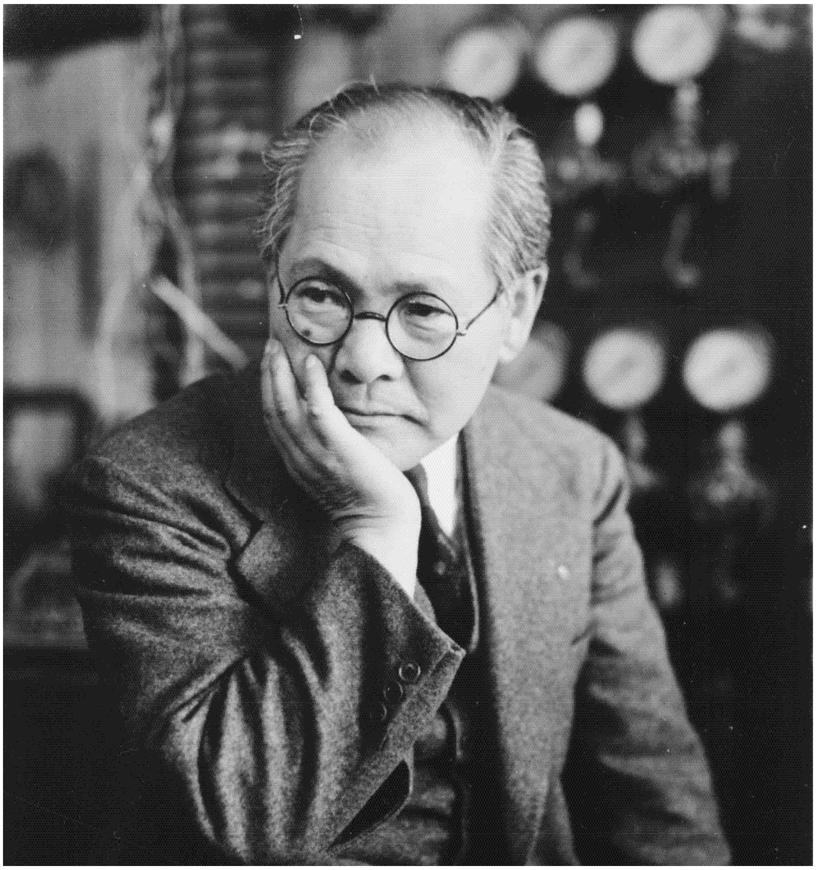
NISHINA

MEMORIAL FOUNDATION

2008



Yoshio Nishina (1890–1951)

Preface

The Nishina Memorial Foundation, which was founded in 1955 to commemorate Dr. Yoshio Nishina's great contribution to the development of modern physics in Japan, has recently celebrated its 50th anniversary. This booklet is aimed at informing the origin, missions and activities of the Foundation to scientists in the world, as the Foundation was based on the initial donation of many distinguished scholars in the world and our activities have been extended world-wide. I hope this will help to strengthen internatioal friendship and collaboration.

March 2008

Toshimitsu Yamazaki
President of the Foundation

Former presidents of the Foundation

Sin-itiro Tomonaga
(1963-1979)

Ryogo Kubo
(1979-1995)

Kazuhiko Nishijima
(1995-2005)

Contents

Yoshio Nishina - Father of Modern Physics in Japan

Yoshio Nishina, referred to in Japan as the Father of Modern Physics, is well known for his theoretical work on the Klein–Nishina formula, which was done with Oskar Klein in the 6 years he spent in Copenhagen under Niels Bohr during the great era of the development of quantum physics. Nishina returned to Tokyo in 1929, and started to build up experimental and theoretical groups at RIKEN. His achievements there were many and great:

(1) encouraging Hideki Yukawa and Sin-itiro Tomonaga to tackle a new frontier of physics, leading eventually to their making breakthroughs in fundamental theoretical physics that won them Nobel prizes;

(2) the discovery of “mesotrons” (the name for Yukawa particles at that time, now called muons) in 1937, which was published in Phys. Rev., parallel to the well known two American groups (Neddremyer-Anderson and Street-Stevenson);

(3) construction of small and large cyclotrons and subsequent discoveries of an important radioisotope ^{237}U and of symmetric fission phenomena by fast neutron irradiation of uranium (1939 - 40), published in Phys. Rev. and Nature;

(4) creation of a new style of research institute, open to external reseachers, an idea inherited from Copenhagen.

During World-War-II his laboratory was severely damaged, and also his cyclotrons were destroyed and thrown into Tokyo Bay right after the end of the war. Nishina devoted all his strength to re-establishing his scientic activities from scratch, but passed away in 1951 with many unfinished attempts left behind. We can say that what Japan is now owes a great deal to Nishina’s major contributions to science and the scientic community.

Birth of the Nishina Memorial Foundation in 1955

Shortly after his death, in 1955, the Nishina Memorial Foundation was established to commemorate the great contributions of Yoshio Nishina and to stimulate scientific development in the field of modern quantum physics. This was made possible by all the efforts of his successors, collaborators, friends, and influential people even outside science, who respected and loved Yoshio Nishina. These included Nishina's best friend, Ernest O. Lawrence, a Nobel Laureate in 1939, who wrote the following to Sin-itiro Tomonaga as early as 1952:

Dear Dr. Tomonaga,

I am glad to hear that you are establishing a research fund in memory of Dr. Nishina. He was truly a great man of science for not only did he himself make fundamental contributions to knowledge, but also he was an inspiring and generous leader whose beneficent influence was felt the world over. Therefore, the establishment of a fund for scientific research would constitute a particularly fitting memorial and I would count it a privilege and an honor to be associated with this worthy undertaking,

Cordially yours,

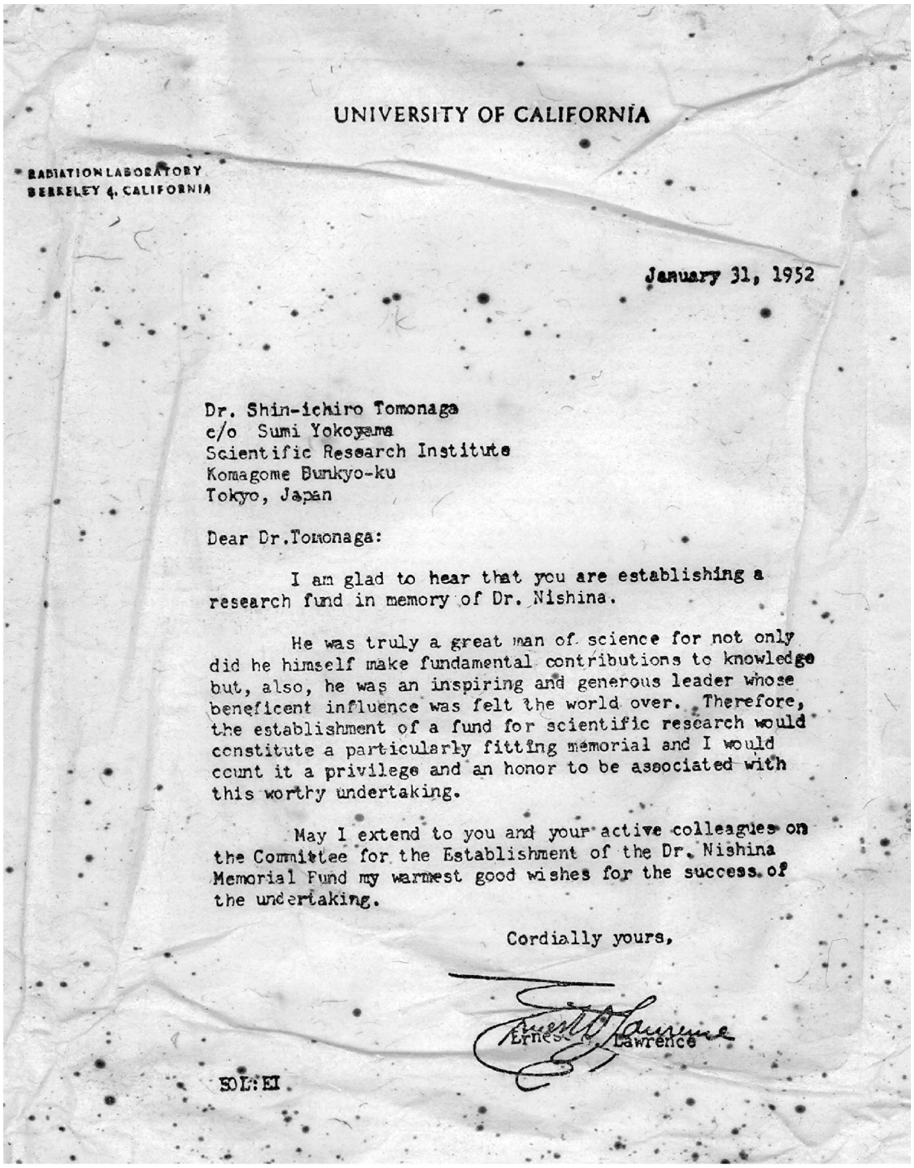
Ernest O. Lawrence

It is to be noted that a substantial amount of the initial funding was donated by 44 distinguished scientists from foreign countries, including 15 Nobel laureates *:

Edoardo Amaldi (Centro di Studio per la Fisica Nucleare, Rome), Philip W. Anderson * (University of Tokyo), John Bardeen * (University of Illinois), C. Bloch (Paris), Nocolas Blömbergen * (Harvard University), J. de Boer (Universiteit van Amsterdam), Niels Bohr * (Copenhagen University), F. Bopp (Institut der Theoretische Physik, Universität Munchen), R.M. Bozorth (Bell Telephone Laboratories), Arthur H. Compton * (Washington University), P. Fleury (Paris), Paul J. Flory * (Cornell University), Frederick C. Frank (University of Bristol), Herbert Fröhlich (The University, Liverpool), Herbert Paul Huber (University of Basle, Basle), Harry C. Kelly (National Science Foundation), J.G. Kirkwood (Yale University), M. Levy (Ecole Normale Superieure, Paris), Per-Olov Loewdin (University of Uppsala, Uppsala), R.E.

Marshak (University of Rochester), H.W. Massey (University College, the University, London), Maria Göppert Mayer * (Argonne National Laboratory), J.E. Mayer (University of Chicago), Nevill F. Mott * (University of Bristol), Robert S. Mulliken * (University of Chicago). Louis E. F. Neel * (Institut Fourier, Grenoble), Marcus L. Oliphant (Australian National University, Canberra), Lars Onsager * (Yale University), Abraham Pais (Princeton University), Rudolph E. Peierls (The University, Edgebaston), F. Perrin (Laboratoire de Physique Atomique et Moleculaire, Paris), A. Proca (Institut Henri Poincare, Paris), Isidor I. Rabi * (Columbia University), Rosenbluth (Los Alamos Scientific Laboratory), Leonard I. Schiff (Stanford University), F. Seitz (University of Illinois), John C. Slater (Massachusetts Institute of Technology), Charles H. Townes * (Columbia University), John H. Van Vleck * (Harvard University), I. Waller (Institute for Mathematical Physics, Uppsala), A. T. Waterman (National Science Foundation), G. Wentzel (University of Chicago), John A. Wheeler (Princeton University), and Chen Ning Yang * (Institute for Advanced Study, Princeton)

The total sum was Yen 947,957. This list bears witness to the admiration felt throughout the world for Yoshio Nishina and the appreciation of his warm and noble character.


UNIVERSITY OF CALIFORNIA

RADIATION LABORATORY
BERKELEY 4, CALIFORNIA

January 31, 1952

Dr. Shin-ichiro Tomonaga
c/o Sumi Yokoyama
Scientific Research Institute
Komagome Bunkyo-ku
Tokyo, Japan

Dear Dr. Tomonaga:

I am glad to hear that you are establishing a research fund in memory of Dr. Nishina.

He was truly a great man of science for not only did he himself make fundamental contributions to knowledge but, also, he was an inspiring and generous leader whose beneficent influence was felt the world over. Therefore, the establishment of a fund for scientific research would constitute a particularly fitting memorial and I would count it a privilege and an honor to be associated with this worthy undertaking.

May I extend to you and your active colleagues on the Committee for the Establishment of the Dr. Nishina Memorial Fund my warmest good wishes for the success of the undertaking.

Cordially yours,

Ernest O. Lawrence

EOL:EI

Figure 1: Letter of E. O. Lawrence to Sin-itiro Tomonaga in 1952

The Missions of the Foundation

The missions of the Nishina Memorial Foundation are:

(i) To award the *Nishina Memorial Prize* to promising young scientists. Already 154 scientists have received the prize, as listed in this booklet. Many of them have gone on to win further prestigious prizes, both national and international, the most notable being the two Nobel Prizes awarded to Leo Esaki (1973) and Masatoshi Koshiba (2002).

(ii) To send young scientists to foreign countries.

(iii) To invite distinguished scientists from foreign countries.

(iv) To give young scientists from developing countiries the chance to engage in research work in Japan.

(v) To explore and record historical events and documents related to Nishina's life and work. Recently, a number of correspondences of Nishina in 1930-40's were found, which are documented and published as a three-volume book, *Collected Correspondence of Yoshio Nishina* (in Japanese, ed. R. Nakane, Y. Nishina, K. Nishina, Y. Yazaki and H. Ezawa, Misuzu Shobo, Tokyo, 2006-2007).

(vi) To deliver Nishina Memorial Lectures. Sin-itiro Tomonaga, the second president of the Foundation, promoted a series of public lectures by inviting distinguished scientists from abroad as well as from Japan. During the first 50 years the number of the NML has exceeded 100 and about 30% of them were delivered by foreign guests. The lectures documented in English were recently published as *Nishina Memorial Lectures - Creators of Modern Physics* as a Springer Lecture Notes in Physics 746 (2007). A list of the Lectures is given in the appendix.

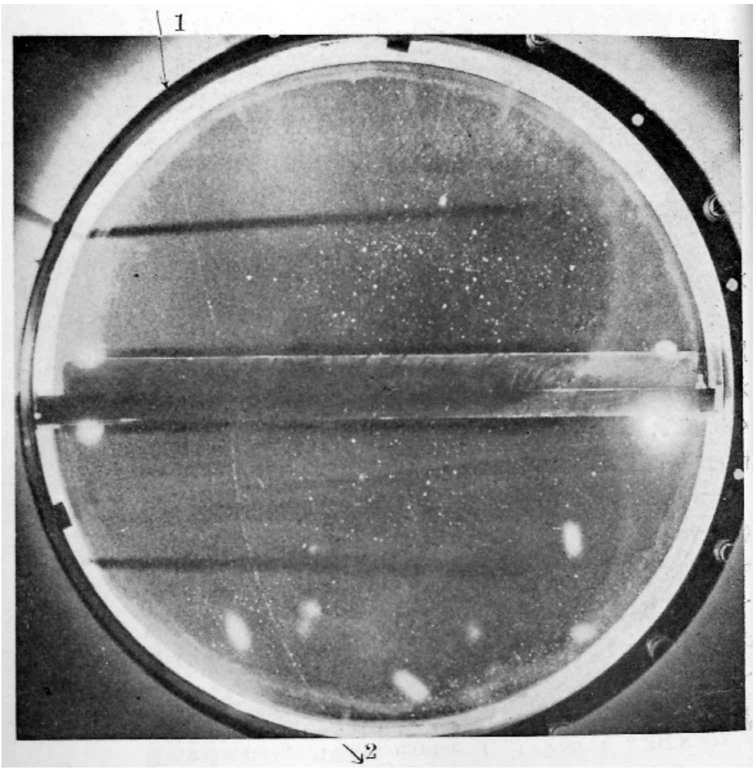


Figure 2: Photograph of a historical Wilson chamber track showing a new cosmic-ray particle, published in Y. Nishina, Kagaku 7 (1937) 408 (submitted August 15, 1937). Y. Nishina, M. Takeuchi and T. Ichimiya reported a mass of 1/7 to 1/10 of the proton mass in Phys. Rev. 52 (1937) 1198 (received August 28, 1937).

Highlight of Nishina's Laboratory

[Discovery of the muon]

Y. Nishina, M. Takeuchi and T. Ichimiya,

Phys. Rev. 52 (1937) 1198

"On the Nature of Cosmic-Ray Particles"

Y. Nishina, M. Takeuchi and T. Ichimiya,

Phys. Rev. 55 (1939) 585

"On the Mass of the Mesotron"

[Discovery of a new radioisotope U-237 and of symmetric fission]

Y. Nishina, T. Yasaki, H. Ezoe, K. Kimura and M. Ikawa,

Nature 144 (1939) 547

"Fission of Thorium by Neutrons

Y. Nishina, T. Yasaki, H. Ezoe, K. Kimura and M. Ikawa,,

Phys. Rev. 57 (1940) 1182L

"Induced beta-activity of Uranium by Fast Neutrons"

Y. Nishina, T. Yasaki, H. Ezoe, K. Kimura and M. Ikawa,,

Nature 146 (1940) 24L

"Fission Products of Uranium by Fast Neutrons"

[Recent historical account]

"Interplay between Yukawa and Tomonaga in the birth of mesons"

by T. Yamazaki

DECEMBER 1, 1937 PHYSICAL REVIEW VOLUME 52

On the Nature of Cosmic-Ray Particles

Y. NISHINA, M. TAKEUCHI, AND T. ICHIMIYA
Institute of Physical and Chemical Research, Tokyo
(Received August 28, 1937)

VARIOUS authors[1] have taken the view that cosmic-ray particles consist of two or more kinds of corpuscles. According to Compton and Bethe, and Auger,[1] the soft component near sea level is thus composed of electrons and the penetrating one of protons. Assuming the theory of showers by Bhabha and Heitler[2] and by Oppenheimer and Carlson[3] to be correct, we ought to be able to distinguish cosmic-ray electrons from protons, if they exist at all, by observing whether or not the particles suffer a large loss of energy and often produce showers on colliding with a lead plate of a suitable thickness.

We carried out such experiments with a lead bar 1.5 cm thick mounted in the middle of a Wilson chamber 40 cm in diameter, which is placed in a magnetic field of about 17,000 oersteds. The operation of the chamber is actuated by the coincidence of two Geiger-Müller tube counters mounted above the chamber, the distance between the counters being about 50 cm. The results showed that at sea level near Tokyo (geomag. lat. 25.4°N) about 10 to 20 percent of cosmic-ray particles of energies, high enough to produce coincidence in the strong magnetic field and pass through the Wilson chamber, consist of electrons and positrons, the rest being heavy particles, since they do not produce showers nor suffer much loss of energy in passing through the lead bar. Among the latter, however, we were

[1] A. H. Compton and H. A. Bethe, Nature **134**, 734 (1934); P. Auger, J. de phys. **6**, 226 (1935); C. D. Anderson and S. H. Neddermeyer, Int. Conf. on Physics, London **1**, 182 (1934); Phys. Rev. **50**, 268 (1936); J. Clay, Physica **3**, 338 (1936); L. Leprince-Ringuet, J. de phys. **7**, 70 (1936); J. Crussard and L. Leprince-Ringuet, Comptes rendus **204**, 240 (1937).

[2] H. J. Bhabha and W. Heitler, Proc. Roy. Soc. **A159**, 432 (1937).

[3] J. F. Carlson and J. R. Oppenheimer, Phys. Rev. **51**, 220 (1937).

surprised to find that there are some particles of both signs, which have much greater penetrating power for lead than protons of the same momentum ($H\rho$) would have. The specific ionization of some tracks is also much smaller than that of protons of the observed $H\rho$. These results can most naturally be explained, if one assumes the existence of new particles of a mass heavier than that of an electron and lighter than that of a proton. At about this time we received the paper of Street and Stevenson[4] and then that of Anderson and Neddermeyer[5] and saw that these authors had obtained similar results. Crussard and Leprince-Ringuet[6] also recognized the existence of particles, which lose less energy through matter than expected for electrons on the theory of showers and produce smaller specific ionization than protons of the same $H\rho$.

We have since then been trying to find a more exact value of the mass of the new particle. Since this seems hardly to radiate in collision with matter, we may for the moment assume that the loss of its energy in passing through lead is entirely due to ionization, although this is probably not always the case as will later be mentioned. In this respect the new particle behaves more like protons than electrons, and especially for energies higher than 10^9 ev we cannot discriminate between the two by specific ionization, because it becomes nearly the same for both. The range in lead, however, as a function either of $H\rho$ or of energy is sensitive to the difference of mass of the particles. We can thus draw a series of mass $H\rho$ curves for various values of ranges. By means of these curves, we can determine the mass of a particle, if we know its range and $H\rho$ from Wilson tracks. As the range we chose 3.5 cm of lead mounted in the middle of our Wilson chamber. In order to filter the electronic component of cosmic rays, a lead block 20 cm thick was inserted between the two controlling counter tubes, placed above the Wilson chamber as described before.

Until now we have obtained only one track which can probably be used for the determination of the mass. The initial value of $H\rho$ of the particle was 7.4×10^5 gauss-cm and after passing through lead it became 4.9×10^5 gauss-cm, showing the loss of about a half of the energy. The loss of energy by ionization and the range in lead calculated from the thickness of the lead bar and the final $H\rho$ are consistent, if we assume the mass in question of the particle to be 1/7 to 1/10 that of the proton. The above values of $H\rho$ and the specific ionization shown by the corresponding tracks are in accordance with the assumed mass. This value must necessarily be provisional and subject to a possible alteration. For accurate determination we need more tracks of appropriate energies.

From our present experimental results we cannot conclude whether the penetrating component of cosmic rays at sea level consists exclusively of these new particles or in part of protons. There are observed some particles which are stopped by 3.5 cm of lead and can be interpreted as protons on the mass $H\rho$ curve. On the other hand we observe some particles of high $H\rho$ which seem to be stopped by the lead plate. The ionization alone cannot account for such a large loss of energy, even if they are protons. We do not know as yet whether we have here to do with the presence of particles heavier than protons or with a certain type of loss of energy other than ionization for the new particles or for protons. The disintegration of lead nuclei caused by these particles must be taken into account in the problem, as can be seen from one of our photographs. Although the exact determination of the composition of the penetrating component of cosmic-ray particles has thus not yet been possible, its large part no doubt consists of the above new particles, through the existence of which various difficulties in connection with cosmic-ray phenomena e.g., ionization, radiative effect,[7] penetrating power, etc. now find a natural explanation.

We should like to express our gratitude to the Imperial Japanese Navy for kind assistances in carrying out these experiments and to Hattori Hokokwai Foundation for a financial grant. We are indebted to Mr. M. Kobayasi for theoretical discussions.

[4] J. C. Street and E. C. Stevenson, Bull. Am. Phys. Soc. **12**, No. 2, 13 (1937).
[5] S. H. Neddermeyer and C. D. Anderson, Phys. Rev. **51**, 884 (1937).
[6] J. Crussard and L. Leprince-Ringuet, J. de phys. **8**, 215 (1937).
[7] E. J. Williams, Phys. Rev. **45**, 729 (1934); *Kernphysik*, (Berlin, 1936), p. 123.

On the Mass of the Mesotron

Since we published[1] the results of mass determination of the mesotron, the existence of which had theoretically been foreseen by Yukawa, we have been continuing the same experiments with the Wilson cloud chamber.

During last September we obtained a photograph shown in Fig. 1. A lead bar 5 cm thick was mounted in the middle

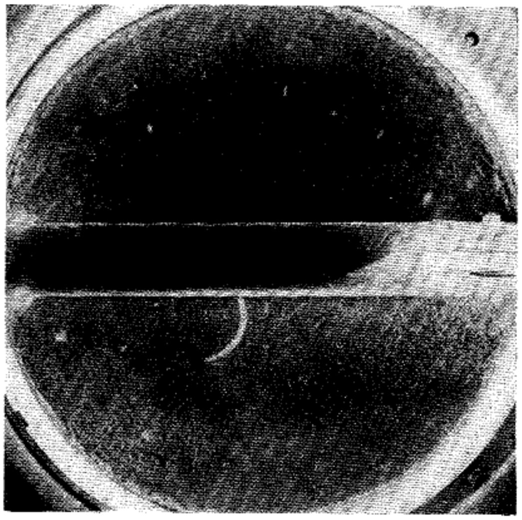


FIG. 1. Wilson track of a mesotron. $H=12{,}600$ oersteds. $H\rho=3.88\times 10^4$ oersted·cm. Observed range = 6.15 cm.

of the chamber 40 cm in diameter, which is filled with air and alcohol vapor, and placed in a magnetic field of about 12,600 oersteds. The operation of the chamber was controlled by two Geiger-Müller tube counters mounted immediately above the chamber. The distance between the counters was about 15 cm. Above the counters was placed a lead block 20 cm thick.

A negatively charged particle of $H\rho=(3.88\pm0.08)\times 10^4$ oersted-cm seems to have been created within the lead bar by a certain non-ionizing agent and was brought to rest in the gas of the chamber, the observed range being 6.15 cm. By taking into account the pressure of the gas, which was between 1.23 and 1.30 atmospheres at 25°C, and a possible inclination of the track with respect to the plane of the chamber, we estimate its range in air of 15°C and 760 mm to lie between 7.3 and 8.1 cm. According to the range-energy curve for the proton given by Livingston and Bethe[2] we calculate the mass of the particle by using the above values of $H\rho$ and range and obtain

$$M_m=(170\pm9)m, \qquad (1)$$

where m is the mass of the electron.

At the end of the range the photograph shows no sign of an electronic track, which would prove the disintegration of the mesotron.

We have recently re-examined the old photograph mentioned in our preceding paper[1] and obtained the following values. A positively charged particle of $H\rho=(7.4\pm0.1)$

$\times 10^5$ oersted·cm passes through a lead bar 3.5 cm thick at an angle of about 47°, the length of the path inside lead thus being 4.8 cm. After traversing the lead bar, $H\rho$ becomes $(5.0\pm0.1)\times10^5$ oersted·cm.

On assuming the mass of the particle, we can calculate its initial and final energies and thus find the loss of energy due to collisions within lead. On the other hand this energy loss can be calculated theoretically, for example, according to Bloch's formula,[3] if we use the assumed mass and the initial energy. The mass of the particle can be adjusted in such a way as to bring both values of the energy loss to agreement. In this manner we formerly obtained with the old data of preliminary measurements

$$M_m=(180\sim260)m. \qquad (2)$$

In these calculations we assumed for Bloch's formula the maximum energy W transferred in a direct collision from the particle to a free electron to be $2mv^2$ according to the nonrelativistic theory, where v is the velocity of the particle. In our case, however, we ought instead to have used a relativistic value

$$W=\frac{2mM_m(1+\eta)E}{m^2+2mM_m\eta+M_m^2}, \qquad (3)$$

as was given by Bhabha,[4] where E is the initial energy of the particle, $\eta=(1-v^2/c^2)^{\frac{1}{2}}$, and c is the velocity of light. If we do this and use the above data of the new measurements, we obtain

$$M_m=(180\pm20)m, \qquad (4)$$

which is in better agreement with the value (1).

A more detailed paper will be published in the Scientific Papers of this Institute.

Y. Nishina
M. Takeuchi
T. Ichimiya

Cosmic-Ray Sub-Committee of Japan Society for the Promotion of Scientific Research,
Institute of Physical and Chemical Research,
Tokyo, Japan,
January 31, 1939.

[1] Y. Nishina, M. Takeuchi and T. Ichimiya, Phys. Rev. **52**, 1198 (1937).
[2] M. S. Livingston and H. A. Bethe, Rev. Mod. Phys. **9**, 268 (1937).
[3] Cf. W. Heitler, *The Quantum Theory of Radiation* (Oxford, 1936), formula (1), p. 218.
[4] H. J. Bhabha, Proc. Roy. Soc. **A164**, 255 (1938).

LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. They cannot undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of NATURE. *No notice is taken of anonymous communications.*

NOTES ON POINTS IN SOME OF THIS WEEK'S LETTERS APPEAR ON P. 555.

CORRESPONDENTS ARE INVITED TO ATTACH SIMILAR SUMMARIES TO THEIR COMMUNICATIONS.

Fission of Thorium by Neutrons

SINCE March 1938, we have been engaged in the study of artificial radioactivity induced in thorium by fast neutrons. We have already reported[1] the production of uranium Y, which was obtained in the course of this investigation.

At that time we had examined the barium and lanthanum fractions from activated thorium and obtained nearly all the periods which Meitner, Strassmann and Hahn[2] found in their study of the artificial radioactivity of thorium, and which Hahn and Strassmann[3] and other authors later identified with those for fission products of uranium and thorium, although our agreements were not exact in some cases and some other periods were obtained in our experiments.

We did not, however, follow closely these lines of investigation, since our attention was directed to a radioactive substance, which was precipitated with bismuth and lead as carriers from hydrochloric acid solution by hydrogen sulphide. We spent much time on the chemical identification of this substance. Its chemical properties were not easy to ascertain, but it was still more difficult to understand the nuclear reactions concerned. Chemical properties suggested that either 'transuranic' or elements of lower atomic number than bismuth were involved, but both these alternatives were difficult to accept at that time. Then, however, came Hahn and Strassmann's discovery of fission processes, and the problem became easier, at least in principle.

From this point of view we have been working on the chemical identification of elements for several months, but have not come yet to final conclusions. In the meantime, results on similar work were published by Bretscher and Cook[4] and by Meitner[5], but exact identification of elements was not given. Although our experiments are still in a very preliminary stage, we should like to give here the results so far obtained, since we are obliged to interrupt our work for some time.

Thorium nitrate, carefully freed from mesothorium as well as from other disintegration products except radiothorium, was exposed to fast neutrons which were produced by bombarding lithium with 3 Mv. deuterons of several microamperes from our cyclotron. The exposure ranged from one to five hours, after which the sample was subjected to chemical separations. Examination of radioactivity showed the production of the following active substances: Bi, Hg, Sb, Sn and Ag. Besides these elements, the following fractions were found to be radioactive: alkali fraction, halogen fraction, Mo-fraction, Se + Au-fraction, Cu + Cd-fraction. Identification of elements in these fractions requires further investigation.

We tested for radioactive lead and arsenic and proved their definite absence. Our chemical separations, however, took at least two or three hours and all radioactivities of short periods must have escaped our detection.

We tried similar experiments also with uranium, and so far have obtained the following radioactive precipitates: Bi, Hg, Ag, Sb + Sn, and Cu + Cd-fraction.

More thorough identification of radioactive elements both from thorium and uranium, and determination of their periods will be made in the future. Chemical procedures and details of the experiments will be given elsewhere.

We should like to acknowledge the assistance given by Messrs. N. Saito and N. Matuura in connexion with the chemical separations.

Y. NISHINA.
T. YASAKI.
H. EZOE.

Nuclear Research Laboratory,
Institute of Physical and
Chemical Research,
Tokyo.

K. KIMURA.
M. IKAWA.

Chemical Institute,
Faculty of Science,
Imperial University of Tokyo.

July 29.

[1] Nishina, Y., Yasaki, T., Kimura, K., and Ikawa, M., NATURE, **142**, 874 (1938).
[2] Meitner, L., Strassmann, F., and Hahn, O., *Z. Phys.*, **109**, 538 (1938).
[3] Hahn, O., and Strassmann, F., *Naturwiss.*, **26**, 756 (1938); **27**, 11 (1939); **27**, 89 (1939).
[4] Bretscher, E., and Cook, L. G., NATURE, **143**, 559 (1939).
[5] Meitner, L., NATURE, **143**, 637 (1939).

Induced β-Activity of Uranium by Fast Neutrons

In the course of experiments on the fission of uranium by fast neutrons,[1] besides fission products the uranium fraction showed a β-activity with a period 6.5 days.

This activity was induced appreciably only by fast neutrons obtained by bombarding lithium with 3-Mev. deuterons from our cyclotron. The experimental procedure was as follows.

A few grams of uranium oxide, U_3O_8, carefully purified and freed from its disintegration products were exposed to fast neutrons for more than fifty hours. After the exposure, a uranium fraction (U_3O_8) was separated and purified from all possible elements produced by fission as well as from its own disintegration products. The most care was given to the removal of lanthanum from the sample, the procedure taking as long as one day. The activity of the irradiated uranium was compared with that of a nonirradiated sample, in order to subtract the growing β-activity due to disintegration products of uranium. The difference thus obtained shows a 6.5-day period. This activity is probably due to U^{237} produced from U^{238} through loss of a neutron, as in the case of the production of UY from thorium.[2] If this is the case, we have here a member of the missing radioactive family $4n+1$.

The sign of the β-rays was shown to be negative and consequently we suspected the production of a radioactive element of atomic number 93, the chemical properties of which are probably homologous to rhenium. From the decay curve it is clear that its period must be very long, if it exists. To search for such an element, the irradiated uranium oxide, which was freed from fission products as well as its own disintegration products as above mentioned, was left for about 7 days, and was then dissolved in nitric acid. The solution, after an addition of perrhenic acid, was treated with ammonium sulphide and then acidified with sulphuric acid. The precipitated rhenium sulphide, after the removal of contaminated sulphur by carbon bisulphide, was examined for β- and α-activities. Neither of them could be found within the error of our experiments. We may thus conclude, as in the case of 23-minute uranium,[3] that the 6.5-day uranium decays also into a very long-lived 93 element. The detailed accounts of the experiments will be given elsewhere.

The above investigations were carried out as a part of the work of the Atomic Nucleus Sub-Committee of the Japan Society for the Promotion of Scientific Research. We acknowledge the assistances given by our laboratory colleagues in connection with the irradiation of samples and by Messrs. N. Saito and N. Matuura regarding the chemical separations.

Y. Nishina
T. Yasaki
H. Ezoe

Nuclear Research Laboratory,
Institute of Physical and Chemical Research,

K. Kimura
M. Ikawa

Chemical Institute,
Faculty of Science,
Imperial University of Tokyo,
Tokyo, Japan,
May 3, 1940.

[1] Y. Nishina, T. Yasaki, H. Ezoe, K. Kimura and M. Ikawa, Nature **144**, 547 (1939); Nature, in press (1940).
[2] Y. Nishina, T. Yasaki, K. Kimura and M. Ikawa, Nature **142**, 874 (1938).
[3] E. Segrè, Phys. Rev. **55**, 1104 (1939).

LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. They cannot undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of NATURE. *No notice is taken of anonymous communications.*

IN THE PRESENT CIRCUMSTANCES, PROOFS OF "LETTERS" WILL NOT BE SUBMITTED TO CORRESPONDENTS OUTSIDE GREAT BRITAIN.

Fission Products of Uranium produced by Fast Neutrons

IN continuation of our experiments on the fission of uranium by fast neutrons, we have been studying decay periods of various isotopes. In this communication we give the results on silver and cadmium isotopes.

The uranium oxide, U_3O_8, carefully purified and freed from its disintegration products just before the experiments, was exposed to fast neutrons produced by bombarding lithium with 3 Mev. deuterons of several microamperes from our cyclotron, as described in our earlier note[1]. The exposure ranged from a few hours to some fifty hours, according to the object of the experiments. From the irradiated sample, silver was separated as iodide or chloride, cadmium as sulphide. Each fraction, carefully freed from the known fission products of uranium such as barium, lanthanum, antimony, tellurium, iodine, molybdenum, etc., was examined for its activity.

The decay curves of the silver fraction, which were obtained from samples exposed for some fifty hours, showed two periods, 7·5 days and 3 hours. The former activity is probably identified with ^{111}Ag [2,3] and the latter with ^{112}Ag [3].

The decay curves of the cadmium fraction, which was obtained from long exposures, showed apparently three periods, fifty minutes, several hours and 2·5 days. The first activity is possibly an isotope reported by Dodé and Pontecorvo[4]. The second one was proved to be ^{117}Cd by the identification of indium activity produced through its series transformation in the following way. Cadmium sulphide from a sample irradiated for 3 hours was dissolved in hydrochloric acid three hours after the initial separation of cadmium. The solution, after an addition of indium nitrate, was treated with an excess of ammonia. The precipitated indium hydroxide was filtered off and examined for the activity. Its half-period was found to be 2·1 hours, which is due to the known isotope of indium ^{117}In [5]. We thus conclude that the activity of the cadmium fraction is due to ^{117}Cd, the half-life of which turns out according to our measurements to be about 5·5 hours.

Similar procedure was taken with the 2·5-day activity. The cadmium sulphide from an irradiated sample of long exposure was left for about twenty hours before dissolution in hydrochloric acid, until the cadmium isotope ^{117}Cd and its daughter product died away. The indium fraction obtained in the same way as above was examined for activity, and a half-life of 4·5 hours was obtained, which we identify with the known radioactive isomer of the stable indium isotope ^{115}In* [5]. As a consequence, we conclude the 2·5-day activity to be due to a cadmium isotope ^{115}Cd.

It should be mentioned that Be + D neutrons from our cyclotron, and also neutrons slowed down by paraffin, do not appreciably produce silver and cadmium activities as above mentioned. The details of the experiments will shortly be given elsewhere.

The above investigations were carried out as a part of the programme of the Atomic Nucleus Sub-Committee of the Japan Society for the Promotion of Scientific Research. We acknowledge the assistance given by our laboratory colleagues in connexion with the irradiation of samples and by Messrs. N. Saito and N. Matuura regarding the chemical separations.

Y. NISHINA.
T. YASAKI.
H. EZOE.

Nuclear Research Laboratory,
Institute of Physical and Chemical Research,
Tokyo.

K. KIMURA.
M. IKAWA.

Chemical Institute,
Faculty of Science,
Imperial University of Tokyo.

May 3.

[1] Nishina, Y., Yasaki, T., Ezoe, H., Kimura, K., and Ikawa, M., NATURE, **144**, 547 (1939).
[2] Kraus, J. D., and Cork, J. M., *Phys. Rev.*, **52**, 763 (1937).
[3] Pool, M. L., *Phys. Rev.*, **53**, 116 (1938).
[4] Dodé, M., and Pontecorvo, B., *C.R.*, **207**, 287 (1938).
[5] Goldhaber, M., Hill, R. D., and Szilard, L., *Phys. Rev.*, **55**, 47 (1939); NATURE, **142**, 521 (1938); Cork, J. M., and Lawson, J. L., *Phys. Rev.*, **56**, 291 (1939).

Invited talk at the Yukawa session of the International Nuclear physics Conference, Tokyo, June 2007

Interplay between Yukawa and Tomonaga in the Birth of Mesons

Toshimitsu Yamazaki

Nishina Memorial Foundation, Honkomagome 2-28-45, Bunkyo-ku, Tokyo 113-8941, Japan

Department of Physics, University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan

RIKEN Nishina Center, Wako-shi, Saitama-ken 351-0198, Japan

Abstract

Light is shed on the early stage in the birth of Yukawa's meson theory, particularly on the interplay between Yukawa and Tomonaga in 1933. The discovery of the muon by Nishina' group in 1937 is also reviewed. It is pointed out that Heisenberg's attempt to explain the nuclear force in terms of the Heitler-London scheme, overcome by Yukawa and abandoned since then, is now being revived as a mechanism for a super strong nuclear force caused by a migrating real $\bar{\mathrm{K}}$ meson.

1. Introduction

It is a great honor and pleasure to have an opportunity to give a talk in this Yukawa Centennial Session. Here, I concentrate on the early stage of the birth of the Yukawa meson. As explained in the previous talk by Professor Sato, Yukawa and Tomonaga were physics classmates at Kyoto University. Very recently, private communications between them in 1933, the eve of the birth of Yukawa's theory, were found [1]. These tell us about a very interesting and intriguing interplay and interaction between these two great physisists, then only students. It is the purpose of my talk to convey my own excitement and impressions from their premature years.

2. The Year 1933 of Advent

Right after the discovery of the neutron by Chadwick in 1932, Heisenberg published his famous work on the nuclear force and nuclear binding phenomena in 1932 [2]. This work affected young Yukawa and Tomonaga greatly. These two freshmen, then only 26 years old, challenged the forefront problems of nuclear physics, and attended the spring meeting of the Japan Physico-Mathematical Society, held in Sendai in 1933.

At that time Heisenberg was stuck to the idea of molecular binding applied to the nuclear force in terms of "Platzwechsel" *a la* Heitler and London [3], who explained for the first time the H-H bonding in the hydrogen molecule quantum mechanically in 1927. The Heitler-London-Heisenberg mechanism can be expressed by a diagram, as shown in Fig. 1 (Left). An electron migrates between the two protons, and a strong bonding force emerges as a quantum mechanical effect. Heisenberg's attempt was to combine the proton and the neutron in a similar fashon.

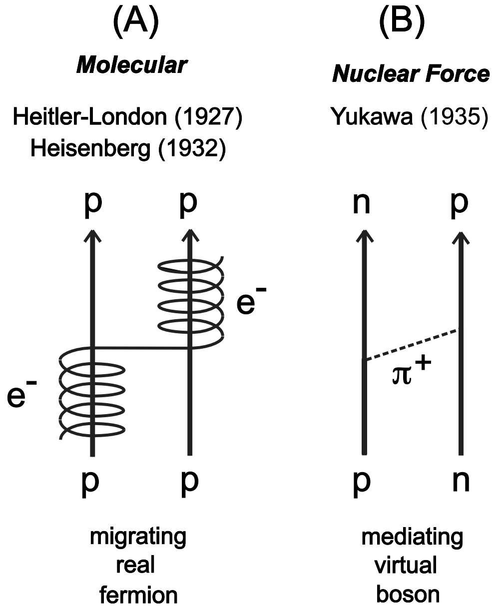


Fig. 1. (Left) Heitler-London-Heisenberg scheme for the nuclear force. Diagram drawn by K. Nishijima. (Right) Yukawa's meson exchange interaction for the nuclear force.

Yukawa took up this problem seriously, and presented his struggling with this problem at this Sendai meeting. The title of his talk was "a consideration of the problem of nuclear electrons". At this meeting Yoshio Nishina, who is called Father of modern physics in Japan, stimulated Yukawa and Tomonaga toward the then developing quantum physics, suggested that Yukawa should consider a boson instead of a fermion to avoid one of the difficulties. The term "Bose electron" was used at that time. It took some time until Yukawa reached his revolutional idea of a mediating virtual meson in the fall of 1934.

At the same meeting Tomonaga presented his work on the deuteron binding energy and the proton-neutron reaction. At that time Tomonaga was a resident physicist in Nishina's laboratory at RIKEN, and was working on a theoretical explanation of the newly obtained experimental data on the interaction between a proton and a neutron, employing various interaction forms. It is striking that he chose the following form for a short-range interaction:

$$J(r) = A \frac{\exp(-\lambda r)}{r} . \quad (1)$$

This was nothing but what would be later called the Yukawa interaction.

Here, a great interplay emerged. After this meeting Tomonaga wrote a rather long letter to Yukawa [4], in which he explained his results in more detail. Figure 2 is a copy of his letter, in which he showed the above interaction form, and told Yukawa about the value of the range parameter λ, he obtained from fitting the experimental values with this interaction form,

$$\lambda = 7 \times 10^{12} \text{ /cm.} \quad (2)$$

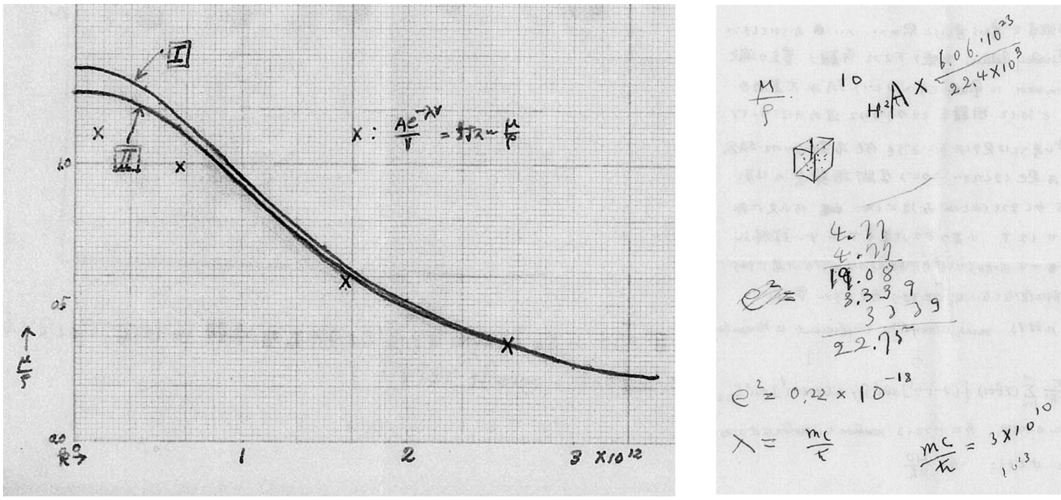


Fig. 2. (Left) Tomonaga's hand-drawn plot of the p-n reaction data with his theoretical fitting using the "Yukawa interaction." (Right) Yukawa's note on the back of Tomonaga's letter. From Ref. [4].

It is extremely interesting that Yukawa jotted some notes on the back of this letter (see Fig. 2, right panel), such as

$$\lambda_{Comton} = \frac{mc}{\hbar} \sim 3 \times 10^{10} \mathrm{cm}^{-1}. \qquad (3)$$

It is very interesting to speculate about what Yukawa was thinking when he made this hand-written estimate of the electron Compton wavelength. If we divide Tomonaga's value by this value, we would obtain the value 230 !!

We can thus imagine that this letter must have had a profound influence on Yukawa, who was in the midst of struggling with the problem of the nuclear force in 1933, but had not yet formulated the idea of the Yukawa interaction, in which the range parameter is related to the mass of the mediating particle.

Tomonaga's work on the range of the p-n interaction was later mentioned in a footnote of Yukawa's first paper [5] as

These calculations were made previously, according to the theory of Heisenberg, by Mr. Tomonaga, to whom the writer owes much....

On the other hand, Tomonaga published this work only in 1936 [6], 3 years after his letter to Yukawa. A similar work on the proton-neutron binding by Bethe and Peierls [7] appeared in the literature in 1935.

3. Yukawa Overcame Heisenberg

At that time, in the spring of 1933, neither Yukawa nor Tomonaga seemed to recognize the deep meaning of the interaction formula (1) and, in particular, the implication of the range parameter, λ, which Tomonaga deduced from experimental data. Heisenberg tried to explain the nuclear force in terms of the Heitler-London scheme, but was not successful. Yukawa as of 1933 also struggled with this problem. Many difficult problems existed: how can a migrating real particle exist in nuclei? Is it a Bose electron? How can the interaction be short-ranged? How can proton + electron be a neutron?

Finally, in the fall of 1934 Yukawa arrived at the concept of a "virtual mediating particle" behind the strong nuclear force. Its diagram is shown in Fig. 1 (Right).

The famous equation

$$[\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \lambda^2]U = 0, \tag{4}$$

given in the first Yukawa paper, published in 1935 [5], represents a force field U with a parameter λ, Here, Yukawa took the form (1) for the short-range interaction of the nuclear force. Yukawa's great discovery was to relate this parameter, which expresses the inverse of the force range, to the mass of a mediating particle, U:

$$\lambda = \frac{mc}{\hbar}. \tag{5}$$

The mass of U was expected to be 200-times larger than the electron mass. Eventually, the Yukawa mesons were discovered. Thus, the Yukawa theory became the fundamental concept in modern physics since 1935.

In contrast, the old idea of Heisenberg based on the Heitler-London scheme was completely abandoned and forgotten in nuclear physics, but we will revisit this problem later.

4. Discovery of the "Mesotron"

Another story I would like to convey is that of the discovery of muons. Nishina constructed a large cloud chamber with a very strong and homogeneous magnetic field to measure cosmic rays. Around 1936-37, there were four experimental groups in the world with the primary purpose of examining the validity of the Bethe-Heitler formula, which had just been derived. Neddermeyer and Anderson [8] were the first to report that there are some particles that do not obey this theory. Such particles were believed to be neither the proton nor the electron (positron), presumably having a mass between that of the proton and the electron. In the same year, similar findings were reported by other groups [9-11]. Among them, two groups succeeded in determining the mass of such intermediate particles. A paper of Nishina, Takeuchi and Ichimiya [10], reporting a value of $m_X/m_e = 180 \pm 20$, the most precise value at that time, was received by Physical Review on August 28, 1937, and was published on December 1. Interestingly, a paper of Steet and Stevenson [11], reporting $m_X/m_e = 130 \pm 30$, was received on October 6, 1937, more than one month later than Nishina's paper, but was published on November 1, one month earlier. This situation resulted from the fact that shipping of the galley proof back and forth between New York and Tokyo took nearly 40 days. Figure 3 shows a cloud-chamber picture of Nishina' group, which was printed in a Japanese science journal, "Kagaku", in September 1937.

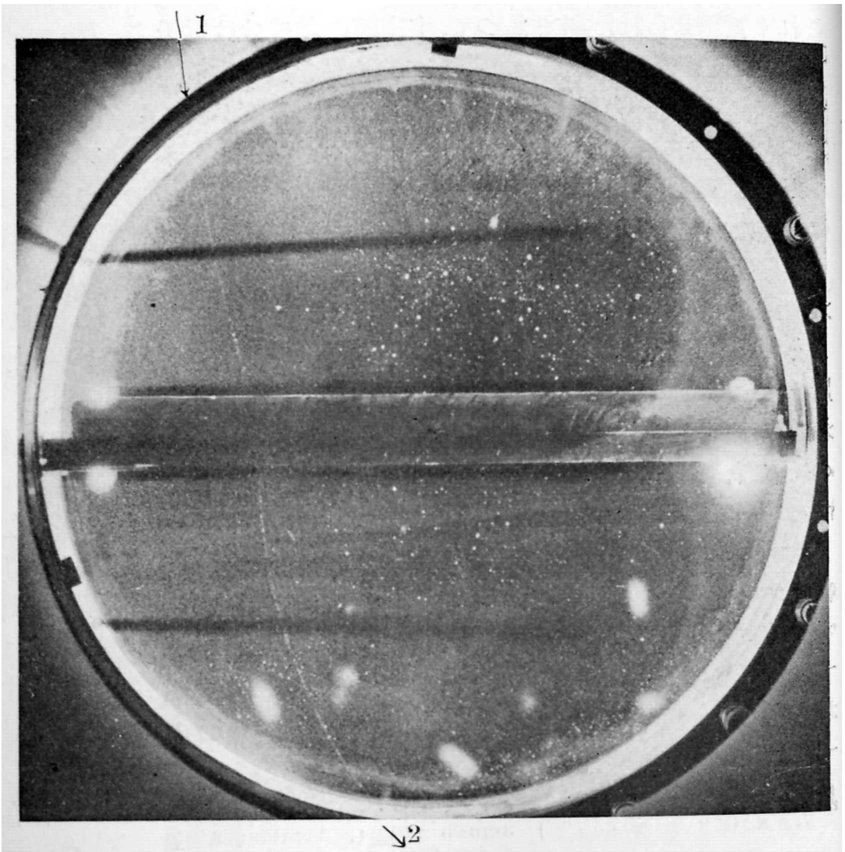


Fig. 3. Photograph of the cloud chamber track of a cosmic ray event taken by Nishina, Takeuchi and Ichimiya of RIKEN. From Nishina in "Kagaku" [12].

Thus, it is fair to say that the two experiments [10,11] were nearly of the same quality and significance. Nevertheless, the experiment of Nishina's group has hardly been recognized in the world. It is a pity that even Japanese physicists are not aware of this great achievement.

5. Heitler-London-Heisenberg scheme revisited

My historical talk may end at this point, but I would like to show two more slides to explain that the Heitler-London-Heisenberg scheme may have profound meaning, 80 years after the Heitler-London paper. Very recently Akaishi and myself predicted the presence of a new nuclear cluster, K^-pp based on the empirically deduced $\bar{K}N$ interaction. In studying its structure from an unconstrained three-body calculation, we found a dynamically organized molecular structure with K^-p as an atomic constituent [13, 14]. A distinct difference is seen in the depth of the attractive potential and the range of the potential. The volume ratio amounts to about 4. This super strong nuclear force, thus introduced, might be the cause for a cold dense nuclear system and kaon condensation. Thus, we have shown that the HLH scheme is revived in a new form of the nuclear force, and its experimental verification in the future would be extremely interesting.

References

[1] "Collected Correspondence of Yoshio Nishina, Vol. I, II (2006), Vol III (2007)" (in Japanese, ed. R. Nakane, Y. Nishina, K. Nishina, Y. Yazaki and H. Ezawa, Misuzu Shobo, Tokyo)

[2] W. Heisenberg, Z. Phys. **77** (1932) 1, **78** (1932) 156, **80** (1933) 587.

[3] W. Heitler and F. London, Z. Phys. **44** (1927) 455.

[4] S. Tomonaga, private letter to H. Yukawa, from the Yukawa Archive (YIFP); documented in Vol. I of [1].

[5] H. Yukawa, Proc. Phys. Math. Soc. Jap. **17** (1935) 48.

[6] Y. Nishina, S. Tomonaga and H. Tamaki, Sci. Papers of the Inst. Phys. Chem. Res. 30 (1936) 61-69.

[7] H.A. Bethe and R. Peierls, Proc. Roy. Soc. **149** (1935) 176-183.

[8] H. Neddermeyer and C. Anderson, Phys. Rev. **51** (1937), 884.

[9] M.M. Jean Crussard and L. Leprince-Ringuet, Compt. Rend. **204** (1937), 240.

[10] Y. Nishina, M. Takeuchi and T. Ichimiya, Phys. Rev. **52** (1937), 1198.

[11] J.C. Street and E.C. Stevenson, Phys. Rev. **52** (1937), 1003.

[12] Y. Nishina, "Kagaku" **7** (1937) 408 (in Japanese).

[13] T. Yamazaki and Y. Akaishi, Proc. Jpn Acad. Ser. B **83** (2007) 144.

[14] T. Yamazaki and Y. Akaishi, Phys. Rev. **C 76** (2007) 045201.

Recipients of Nishina Memorial Prizes

Year	Name	Affiliation	Subject
1955	**Koreichi OGATA**	Faculty of Science, Osaka University	Completion of a large mass spectrometer
	Kazuhiko NISHIJIMA	Faculty of Science, Osaka City University	Transformation of elementary particles
1956	**Kei YOSHIDA**	Faculty of Science, Osaka University	Magnetic anisotropic energy in antiferromagnetism
	Shingo MITSUI	Faculty of Agriculture, University of Tokyo	Study of botanical fertilization by means of isotopes
	Susumu NISHIGAKI	National Inatitute for Agrotechnology	
	Tomoji EGAWA	National Institute for Agrotechnology	
	Tsunezo USHIODA	Sericulture Experimental Station	
1957	**Ryogo KUBO**	Faculty of Science, University of Tokyo	Statistical mechanics of irreversible processes
1958	**Kenzo SUGIMOTO**	Faculty of Science, Osaka University	Measurements of magnetic dipole and electric quadrupole moments of nuclear excited states
	Katsuro SAWADA	Tokyo University of Education	Study of the correlation energy of electron gas
1959	**Leo ESAKI**	Sony Co., Ltd	Invention of the Esaki diode
	Ryohei NAKANE	The Institute of Physical and Chemical Research	Isotope concentration by chemical exchange reactions
1960	**Akio YOSHIMORI**	Faculty of Science, Osaka City University	Theory of helical spin ordering in magnetic crystals
1961	**Kiyoshi NIU**	Institute for Nuclear Study, University of Tokyo	Fireball model for multiple meson production
	Shuji FUKUI	Faculty of Science, Nagoya University,	Study and development of the discharge chamber
	Sigenori MIYAMOTO	Faculty of Science, Osaka City University	
	Takeo MATSUBARA	Faculty of Science, Kyoto University	A new method in quantum statistical mechanics
1962	**Kazuo TAKAYAMA**	Institute of Plasma Physics, Nagoya University	Study of low-density plasma - invention of the resonant probe method
	Wataru SASAKI	Electrotechnical Laboratory, Agency of Industrial Science and Technology	Study of the hot electron anisotropy in germanium
1963	**Chushiro HAYASHI**	Faculty if Science, Kyoto University	Study of the stellar nuclear evolution
1964	**Giiti IWATA**	Faculty of Science, University of Tokyo	Study of dynamics of electrons and ions in static electric and magnetic fields
	Masao SEYA	Optical Science Laboratory, Tokyo University of Education	Vacuum ultraviolet spectrometer
1965	**Kenji MITANI**	College of General Education, Kyoto University	Study on the negative absorption of weakly ionized plasma at the cyclotron frequency
	Shigetoshi TANAKA	Institute of Plasma Physics, Nagoya University	
	Saburo MIYAKE	Faculty of Science, Osaka City University	Study of cosmic-ray muons and neutrinos

Year	Name	Affiliation	Subject
1966	**Minoru ODA**	Institute for Astronautical Research, University of Tokyo	Determination of the location of SCO-X-1
	Yutaka TOYOZAWA	Institute for Solid State Physics, University of Tokyo	Dynamical theory of optical properties in solid
1967	**Shuzo OGAWA**	Faculty of Science, Hiroshima University	Study of the symmetry of fundamental particles
	Yoshio YAMAGUCHI	Institute for Nuclear Study, University of Tokyo	
	Jun NISHIMURA	Institute of Space and Astronautical Science, University of Tokyo	Study of the transverse momentum in ultra-high energy reactions
1968	**Hazime MORI**	Faculty of Science, Kyushu University	Statistical mechanics of non-equilibrium states
	Jun KONDO	Electrotechnical Laboratory, Agency of Industrial Science and Technology	Clarification of the resistance minimum in dilute alloys
1969	**Hisashi MATSUDA**	College of General Education, Osaka University	Development of a large-dispersion mass separator for precise atomic mass measurements
	Hiroyuki IKEZI	Institute of Plasma Physics, Nagoya University	Study of the ion-wave echo
	Kyoji NISHIKAWA	Faculty of Science, Kyoto University	
1970	**Kunihiko KIGOSHI**	Faculty of Science, Gakushuin University	Study of the Carbon-14 dating
	Tetsuji NISHIKAWA	Faculty of Science, University of Tokyo	Basic study of linear accelerators
1971	**Hirotaka SUGAWARA**	Institute for Nuclear Study, University of Tokyo	Application of the symmetry in fundamental particles
	Haruhiko MORINAGA	Department of Physics, Technical University of Munich	Invention of in-beam gamma-ray spectroscopy and study of nuclear structure
1972	**Kyozi KAWASAKI**	Department of Physics, Temple University	Dynamical theory of critical phenomena
	Kazumi MAKI	Faculty of Science, Tohoku University	Theoretical study of supercondoctors
1973	**Noboru NAKANISHI**	Research Institute for Mathematical Sciences, Kyoto University	Analyses of characteristics of the scattering amplitude in the quantum field theory
	Humitaka SATO	Institute for Fundamental Physics, Kyoto University	Discovery of a new solution of the gravitaional field equation and its application to cosmological physics
	Akira TOMIMATSU	Institute for Theoretical Physics, Hiroshima University	
1974	**Eizo OTSUKA**	College of General Education, Osaka University	Study of the electron transport in semiconductors by means of the cyclotron resonance
	Bunji SAKITA	City College of New York	Supermultiplet and duality theories of elementary particles
1975	**Toshimitsu YAMAZAKI**	Faculty of Science, University of Tokyo	Discovery of the mesonic effect in nuclear magnetic moments
	Eiichi HANAMURA	Institute for Solid State Physics, University of Tokyo	Theoretical study of many-exciton systems

Year	Name	Affiliation	Subject
1976	**Akira ISOYA**	Faculty of Science, Kyushu University	Study of the high-voltage electrostatic accelerator and its development
	Susumu OKUBO	Faculty of Science, Rochester University	Discovery of a new selection rule in the strong interaction of elementary particles
	Jugoro IIZUKA	Faculty of Science, Nagoya University	
1977	**Shigeo SHIONOYA**	Institute for Solid State Physics, University of Tokyo	Study of the high-density excitation effect in semiconductors by means of the picosecond spectroscopy
	Ziro MAKI	Institute for Fundamental Physics, Kyoto University	The SU(4) model of elementary particles
	Yasuo HARA	Institute of Physics, Tsukuba University	
1978	**Eizi HIROTA**	Institute for Molecular Science	Study of free radicals by means of high-resolution, high-sensitivity spectrosopy
	Akito ARIMA	Faculty of Science, University of Tokyo	Theoreical study of the collective motion of nuclei
	Toshio MARUMORI	Institute for Nuclear Study, University of Tokyo	
1979	**Toru MORIYA**	Institute for Solid State Physics, University of Tokyo	Theory of itinerant electron ferromagnetism
	Makoto KOBAYASHI	National Laboratory of High Energy Physics (KEK)	A new model for elementary particles
	Toshihide MASKAWA	Institute for Nuclear Study, University of Tokyo	
1980	**Muneyuki DATE**	Faculty of Science, Osaka University	Generation of ultra-high magnetic field
	Yoshiharu TORIZUKA	Laboratory of Nuclear Science, Tohoku University	Study of the giant resonances of nuclei
	Taichiro KUGO	Faculty of Science, Kyoto University	Theory of the convariant quantization of the non-Abelian gauge field theory
	Izumi OJIMA	Institute for Advanced Study, Princeton	
1981	**Daiichiro SUGIMOTO**	Colledge of General Education, University of Tokyo	Evolution of nearby dual star system
	Motohiko YOSHIMURA	National Laboratory of High Energy Physics (KEK)	The origin of the baryon number in the universe
1982	**Tsuneya ANDO**	Institute of Applied Physics, Tsukuba University	Theoretical study of the two-dimensional electron system in the MOS inversion layer
	Akira TONOMURA	Central Resarch Laboratory, Hitachi Co. Ltd	Development of the electron holography and its application
1983	**Taiji YAMANOUCHI**	Fermi National Accelerator Laboratory	Contribution to the discovery of the Upsilon particles
	Akimasa MASUDA	Faculty of Science, University of Tokyo	Precise microscopic measurements of rare earth elements and its application to space and earth science

Year	Name	Affiliation	Subject
1984	**Tohru EGUCHI**	Faculty of Science, University of Tokyo	The lattice gauge theory
	Hikaru KAWAI	Physics Department, Cornell University	
	Yoshikazu ISHIKAWA	Faculty of Science, Tohoku University	Study of the metal ferromagnetism by means of neutron scattering
	Shinji KAWAJI	Faculty of Science, Gakushuin University	Experimental studies of the negative magnetoresistance and quantum Hall effect in the two-dimensional electron system
1985	**Toyoichi TANAKA**	Masachusetts Institute of Technology	Study of phase transitions of gel
	Sumio IIJIMA	Research Development Cooperation of Japan	Dynamical observation of few-atom ensembles
	Yasuo TANAKA	Institute for Space and Astronautical Science	Study of neutron stars using the satellite Temma
1986	**Masuo SUZUKI**	Faculty of Science, University of Tokyo	Statistical physics of phase transition ordering and quantum many-body systems
	Kazuo FUJIKAWA	Institute for Theoretical Phyiscs, Hiroshima University	Study of the anomaly in quantum field theory
	Tetsuya SATO	Center for Nuclear Fusion Theory, Hiroshima University	Nonlinear dynamics of dissipative magnetohydrodynamic plasma
1987	**Kunio TAKAYANAGI**	Department of Physics, Tokyo Institute of Technology	Study of the surface structure of silicon
	Masaki MORIMOTO	Tokyo Astronomical Observatory, University of Tokyo	Development of millimeterwave astronomy
	Norio KAIFU		
	Masatoshi KOSHIBA	Faculty of Science, Tokai University	Observation of the neutrinos from supernova explosion
	Yoji TOTSUKA	ICEPP, University of Tokyo	
	Teruhiro SUDA	Institute of Cosmic Ray Research, University of Tokyo	
1988	**Toshio MATSUMOTO**	Faculty of Science, Nagoya University	Observation of a submillimeterwave spectrum of the cosmic background radiation
	Keiji KIKKAWA	Faculty of Science, Osaka University	Field theory of the string
	Gunzi SAITO	Institue for Solid State Phyisics, University of Tokyo	New design and synthesis of organic superconductors
1989	**Isao TANIHATA**	The Institute of Physical and Chemical Research (RIKEN)	Study of nuclei by using unstable nuclear beams
	Kenichi NOMOTO	Faculty of Science, University of Tokyo	Theoretical study of supernova
1990	**Katsuhiko SATO**	Faculty of Science, University of Tokyo	Study of particle cosmology
	Yoshinori TOKURA	Faculty of Science, University of Tokyo	Discovery of electron-type copperoxide superconductors
	Kaoru YOKOYA	National Laboratory of High Energy Physics (KEK)	Study of the beam-beam interaction in a linear collider

Year	Name	Affiliation	Subject
1991	**Hideo KITAMURA**	National Laboratory of High Energy Physics (KEK)	Development of the insertion-type light source
	Shuji SAITO	Institute for Molecular Science	Spectroscopic study of intersteller molecules
	Miki WADATI	Faculty of Science, Universuty of Tokyo	Soliton physics and its application
1992	**Yoshihisa YAMAMO-TO**	NTT Fundamental Research Institute	Creation of photon number squeezed states and the control of spontaneous emission
	Yoshichika ONUKI	Institute of Material Engineering, Tsukuba University	Study on the Fermi surface of itinerent heavy-electron systems
	Akira HASEGAWA	College of General Education, Niigata University	
	Tsutomu YANAGIDA	Faculty of Science, Tohoku University	The see-saw mechanism for neutrino masses
1993	**Kimitaka ITOH**	National Institute for Fusion Science	Theory of the anomalous transport and the L-H transition in high temperatureplasmas
	Sanae ITOH-INOUE	Research Institute for Applied Mechanics, Kyushu University	
	Koichi KATSUMATA	The Institute of Physical and Chemical Research (RIKEN)	Study of a new type of magnetic phase transition
1994	**Arisato KAWABATA**	Faculty of Science, Gakushuin University	Theory on the Anderson localization and quantum transport in mesoscopic systems
	Tetsumi TANABE	Institue for Nuclear Study, University of Tokyo	Precise measurement of electron-molecule collisions by means of a cooler ring
	Yoichi IWASAKI	Institute of Physics, Tsukuba University	Large-scale numerical simulations for the lattice QCD
	Akira UKAWA	Institute of Physics, Tsukuba University	
	Masanori OKAWA	National Laboratory of High Energy Physics (KEK)	
	Masataka FUKUGITA	Institute for Fundamental Physics, Kyoto University	
1995	**Takeo SATOH**	Graduate School of Science, Tohoku University	Experimental studies of quantum phase separation at ultra-low temperatures
	Norio KAWAKAMI	Graduate School of Engeering, Osaka University	Study of onedimensional electron systems based on conformal field theory
	Sung-Kil YANG	Institute of Physics, Tsukuba University	
1996	**Shuji NAKAMURA**	Nichia Chemical Industry, Ltd	Study of very short wavelength semiconductor LASER
	Kingo ITAYA	Faculty of Engineering, Tohoku University	Clarification of the atomic processes at the boundary of solid and liquid
	Naomasa NAKAI	National Astronomical Observatory	Discovery of the giant black hole at the Galaxy center
	Makoto INOUE	National Astronomical Observatory	
	Makoto MIYOSHI	National Astronomical Observatory	

Year	Name	Affiliation	Subject
1997	**Tadashi KIFUNE**	Institute for Cosmic Ray Research, University of Tokyo	Study of ultra-high energy gamma ray emitters
	Toru TANIMORI	Faculty of Science, Tokyo Institute of Technology	
	Ichiro SANDA	Faculty of Science, Nagoya University	Theory of CP violation in the B-meson system
	Hiroshi YASUOKA	Institute for Solid State Physics, University of Tokyo	Discovery of the spin-gap in high-temperature superconductors
1998	**Jun AKIMITSU**	College of Science and Engineering, Aoyama Gakuin University	Discovery of superconductivity in the material of ladder structure
	Fujio SHIMIZU	Institute for Laser Science, University of Electro-Communications	Exploration of atomic wave holography
	Kunitaka KONDO	Institute of Physics, Tsukuba University	Contribution to the discovery of the top quark
1999	**Kenzo INOUE**	Faculty of Science, Kyushu University	Quantum symmetry breaking of electro-weak interaction in the supersymmetric standard model
	Akira KAKUTO	Kyushu School of Engineering, Kinki University nications	
	Takaaki KAJITA	Institute for Cosmic Ray Research, University of Tokyo	Discovery of the atmospheric neutrino anomaly
	Yasunobu NAKAMURA	Fundamental and Environmental Research Laboratories, NEC,	Observation and control of coherent two-level systems by using superconducting elements
2000	**Shuji ORITO**	Graduate School of Science, University of Tokyo	Observation of cosmic antiprotons
	Akira YAMAMOTO	High Energy Accelerator Research Organization	
	Ken-ichi KONISHI	Physics Department, Pisa University	Discovery of the Konishi anomaly
	Hisashi HORIUCHI	Faculty of Science, Kyoto University	Study of nuclei by means of molecular dynamics for fermions
2001	**Yoichiro SUZUKI**	Institute for Cosmic Ray Research, University of Tokyo	Discovery of neutrino oscillation by precise observation of solar neutrinos
	Masayuki NAKAHATA	Institute for Cosmic Ray Research, University of Tokyo	
	Fumihiko TAKASAKI	High Energy Accelerator Research Organization (KEK)	Discovery of CP violation in the B-meson decay
	Katsunobu OIDE	High Energy Accelerator Research Organization (KEK)	
	Kiichi AMAYA	Faculty of Engineering Science, Osaka University	Discovery of the superconductivity of oxygen and iron under very high pressure
	Katsuya SHIMIZU	Faculty of Engineering Science, Osaka University	
2002	**Katsuzi KOYAMA**	Graduate School of Science, Kyoto University	Cosmic-ray acceleration in supernova remnants

Year	Name	Affiliation	Subject
	Seigo TARUCHA	Graduate School of Science, University of Tokyo	Generation of artificial atoms and molecules
	Yasuki NAGAI	Research Center for Nuclear Physics, Osaka University	Study of fast neutron capture by nuclei
	Masayuki IGASHIRA	Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology	
2003	**Yoshio KITAOKA**	Graduate School of Engineering Science, Osaka University	Clarification of the new superconducting state by means of nuclear magnetic resonance
	Atsuto SUZUKI	Graduate School of Science, Tohoku University	Observation of the disappearance of reactor antineutrinos
	Takashi NAKANO	Research Center for Nuclear Physics, Osaka University	Discovery of a new particle by using LASER Compton gamma rays
2004	**Kimio NIWA**	Graduate School of Science, Nagoya University	Discovery of the tau neutrino by fully automatized scanning device for nuclear emulsion
	Jaw-Shen TSAI	Fundamental and Environmental Research Laboratory, NEC & RIKEN	Realization of quantum entanglement of two quantum bits by Josephson junctions
2005	**Naoto NAGAOSA**	Graduate School of Engineering, University of Tokyo	Theoretical study of the anomalous Hall effect
	Koichiro NISHIKAWA	Graduate School of Science, Kyoto University	Observation of long-base-line neutrino oscillation with an accelerator neutrino beam
	Kosuke MORITA	The Institute of Physical and Chemical Research (RIKEN)	Synthesis of a new 113th superheavy element
2006	**Toshiki TAJIMA**	Advanced Photon Research Center, JAERI Kansai	Pioneering studies of plasma electron acceleration by laser
	Hidetoshi NISHIMORI	Faculty of Science, Tokyo Institute of Technology	Discovery of Nishimori line in random-spin systems
	Osamu MISHIMA	National Institute for Materials Science	Phase transition of the water/amorphous ice - experimental studies of polyamorphism
2007	**Yutaka HOSOTANI**	Graduate School of Science, Osaka University	Discovery of the Hosotani mechanism

Nishina Memorial Lectures

Year	*Speaker*	Title
1955	*Sin-itiro Tomonaga*	Cosmic Rays
	Takeo Hatanaka	Changing Universe
1956	*Cecil F. Powell*	Cosmic Rays
	Oskar B. Klein	Problems Related to Small and Big Numbers of Physics
	Oskar B. Klein	Gravitation Interaction between Dirac Particles
	Seishi Kikuchi	Structure of Matter
	Hiroo Kumagai	Experiments on Atomic Nuclei
1957	*Chihiro Ishii*	Norikura Observatory and Cosmic-Ray Observation by Balloon
	Yuji Hagiwara	Relation between the Sun and the Earth
	Chihiro Ishi	My Twenty Years of Cosmic-Ray Research
1958	*Jean L. Destouches*	Non-Linear Theory of Field
	Robert Serber	Strong Coupling Theory
	Shoten Oka	Biological Action of Radiation and the Order
1959	*John M. Blatt*	The Status of the Theory of Superconductivity
	Sin-itiro Tomonaga	Development of the Atomism
	Victor F. Weisskopf	Elementary Particles
	Yoshio Suga	Theory of Thermoelectric Refrigeration and its Applications
	Yuichiro Aono	The Sun and the Ionosphere
1960	*Sin-itiro Tomonaga*	Discovery of Nuclear Power
	Ryoukiti Sagane	Nuclear Power Generation
	J. Robert Oppenheimer	New Developments in Elementary Particle Theory
	L. Rosenfeld	Foundation of the Quantum Mechnics
	M. A. Markov	The Atomism in Modern Physics
	Sin-itiro Tomonaga	The Radioactivity
1961	*S.N. Vernov*	Radiation Belt Observed by Rockets and Artificial Satellites in the Soviet Union
	Donald A. Glaser	Bubble Chambers and Elementary Particle Physics
	Minoru Oda	The Archeology of the Cosmos
1962	*E. W. Muller*	Field Ion Microscope
	Moriso Hirata	Physics of Cracks
1963	*Mitio Hatoyama*	Electronics Age and Transistors
	Noboru Takagi	Observation Rocket and Cosmic Science
1965	*Isidol I. Rabi*	Social Responsibility of Scientists
	Hideki Yukawa	Dr. Nishina, Mr. Tomonaga and I
1966	*Sin-itiro Tomonaga*	Development of Quantum Electrodynamics:Personal Recollection
	Satio Hayakawa	Radiation Reveals the Universe
1967	*Werner C. Heisenberg*	Abstraction in Modern Science ★★

	Juntaro Kamahora	Early Days of Cancer Research
1968	*Kodi Husimi*	Early Days of Nuclear Fusion and Plasma Research
1969	*Eiichi Goto*	Forte and Weak of Computer
1970	*Sin-itiro Tomonaga*	Reminiscences of Nuclear Physics
	Kouichi Shimoda	Advancement of Laser Science
1971	*Hideki Yukawa*	Character of Physicists
1972	*Itaru Watanabe*	Life Science and Human's Futures
1973	*Chuji Tsuboi*	The Earth Which is Alive
1974	*Sin-itiro Tomonaga*	Changing Visions of the Universe:from the Copernicus to Einstein
1975	Minoru Oda	X-ray Stars and Black Holes
1976	*Sin-itiro Tomonaga*	Introduction to Atomic Physics
1977	*Kodi Husimi*	Dream and Reality of Fusion Energy
1978	*Felix Bloch*	History of NMR
	Felix Bloch	Early Days of Quantum Mechanics
	Norimune Aida	New Research of Friction Phenomena
1979	*Satoshi Watanabe*	Cooperation Phenomenon and Pattern Recognition
1980	*Julian Schwinger*	Two Shakers of Physics ★★
	Morikazu Toda	Natural Phenomenon and Nonlinear Mathematics
1981	*R. E. Peierls*	Model-making in Physics
	Tetsuji Nishikawa	Search for Quarks - Ultimate Elementary Particles
	W.K.H. Panofsky	From Linear Accelerators to Linear Colliders
	Hiroichi Hasegawa	Cosmic Dusts and the Birth of Planets
1982	*Sadao Nakajima*	World of Extremely Low Temperature
	Tasuku Honjo	Moving Genes : Molecular Genetics Basis of Immunological Phenomenon
1983	*H. Schopper*	CERN and LEP
	Chien-Shiung Wu	The Discovery of the Parity Violation in Weak Interaction and its Recent Development ★★
	Gerard't Hooft	Is Quantum Field Theory a Theory ?
	John Bardeen	Evidence for Quantum Tunneling in Quasi-One-Dimensional Metals
1984	*E. M. Lifshitz*	L.D. Landau ? His Life and Work
	Humitaka Sato	Birth of the Universe
	Freeman J. Dyson	Origins of Life ★★
	Yasuo Tanaka	X-ray Astronomy in Japan
1985	*Carlo Rubbia*	Discovery of Weak Bosons
	Yoichiro Nambu	Is "the Elementary Particle" a Particle?
	Richard P. Feynman	The Computing Machines in the Future ★★
	Ben R. Mottelson	Niels Bohr and Modern Physics ★★
	Mikio Namiki	Quantum Mechanics and Observation Problems
1986	*Aaron Klug*	Hierarchies in Chromosome Structure
	Masaki Morimoto	Radio Waves Reveal the Universe

1987	*Ken Kikuchi*	Searches for Elementary Particles by Large Accelerators
	Nikolai G. Basov	Physical and Chemical Processes in Electroionization Discharge Plasma
	Toshimitsu Yamazaki	Muon Spin: Rotation, Relaxation, and Resonance
1988	*Kai Siegbahn*	From Atomic Physics to Surface Science ★★
	Masaki Morimoto	Ten Years in Radio Astrophysics
	Masatoshi Koshiba	Neutrino Astrophysics: Birth and the Future
1989	*Philip W. Anderson*	Theoretical Paradigms for the Sciences of Complexity ★★
	Philip W. Anderson	Some Ideas on the Aesthetics of Science ★★
	Humitaka Sato	Birth of the Universe
	Kunihiko Kigoshi	Radiometric Dating
1990	*Leon V. Hove*	Particle Physics and Cosmology ★★
	Nobuhiko Saito	Protein: Reading and Decoding the Language of Amino Acid
	*** see footnote ***	Yoshio Nishina Centennial Symposium — Evolutional Trends in the Physical Sciences
1991	*Daiichiro Sugimoto*	New Method in Computer Physics: From Cosmos to Protein
1992	*Mikio Namiki*	Mystery in Modern Science: Quantum Phenomenon, Character of Microscopic World in Non-Daily Life
	Charles H. Townes	What's Going on in the Center of Our Galaxy
	Yutaka Toyosawa	Paradox and Truth of Quantum Mechanics
1993	*Heinrich Rohrer*	The New World of the Nanometer ★★
	Heinrich Rohrer	Challenge for Proximal Probe Methods ★★
	James W. Cronin	The Experimemtal Discovery of CP Violation ★★
	Jun Kondo	Peculiar Behavior of Conduction Electrons
1994	*Kinichiro Miura*	Road to Protein Design
1995	*Joseph H. Taylor*	Binary Pulsers and Relativistic Gravity
	Keiichi Maeda	Black Hole and Gravitational Wave: New Eyes for Observing the Universe in the 21st Century
1996	*Eiji Hirota*	Science of Free Radical: Current Status and the Future
1997	*Ilya Prigogine*	Is Future Given?
	Makoto Inoue	Observing a Huge Back Hole
1998	*Pierre-Gilles de Gennes*	From Rice to Snow ★★
	Pierre-Gilles de Gennes	Artificial Muscle
	Harold W. Kroto	Science: A Round Peg in a Square World ★★
	Shuji Nakamura	Progress of Blue Luminescence Device : LED that Replaces Light Bulb
1999	*Norio Kaifu*	SUBARU Telescope and New Space Observation
2000	*Claude Cohen-Tannoudji*	Manipulating Atoms with Light
	Jerome Isaac Friedman	Are We Really Made of Quarks ? ★★
	Akira Tonomura	Look into the Quantum World
2001	*Sumio Iijima*	Basis and Application of Carbon Nanotubes
2002	*Yoji Totsuka*	Investigation of the Mystery of the Neutrino

2003	*Martinus J.G. Veltman*	Very Elementary Particle Physics ★★
	Atsuto Suzuki	Investigating the Depth of the Elementary Particle, the Earth, and the Sun with the Neutrino
2004	*Yasunobu Nakamura*	Superconducting Quantum Bit：Quantum Mechanics in the Electric Circuit
2005	*Chen Ning Yang*	My Life as a Physicist and Teacher
	Chen Ning Yang	The Klein-Nishina Formula and Quantum Electrodynamics ★★
	Muneyuki Date	Progress of Condensed Matter Science as Seen in Nishina Memorial Prizes
	Kazuhiko Nishijima	Yoshio Nishina and the Origin of Elementary Particle Physics in Japan
2006	*Makoto Kobayashi*	Whereabouts of Elementary Particle Physics
2007	*Kosuke Morita*	Search for New Superheavy Elements

* R. Kubo ★★, J. Kondo, M. Kotani, A. Bohr, G. Ekspong, R. Peierls, L.M. Ledreman, Y. Nambu, B. Mottelson, P. Kienle, S. Nagamiya, M. Oda, L.P. Kadanoff, M. Suzuki, B.B. Kadomtsev, J. Schwinger, V.L. Ginzburg, C.N. Yang, Yu.A. Ossipyan, H. Haken, J.J. Hopfield, and A. Klug, published as Springer Proceedings in Physics 57 “Evolutional Trends in the Physical Sciences”, M. Suzuki and R. Kubo, eds.,1991, Springer Verlag.

★★ Reproduced in “Nishina Memorial Lectures - Creators of Modern Physics,” Lecture Notes in Physics 746 (Springer Verlag, 2007)