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LABORATORY OF NUCLEAR REACTION

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and

NUCLEAR SCIENCE RESEARCH FACILITY

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Laboratory of Nuclear Reaction and Nuclear Science Research Facility are successors to K. Kimura Laboratory, whose history until 1951 is described in ref. 1) and that from 1952 to 1966 in ref. 2). Laboratory of Nuclear Reaction succeeded mainly the research activities in the field of the experimental nuclear physics, and the Nuclear Science Research Facility succeeded mainly the research activities in the field of the accelerator physics and researches using the beam from the cyclotron in collaboration with members of other organizations. Later, when the Yukawa Laboratory was ceased, its activity was transfered to the Laboratory of Nuclear Reaction in 1968. But, in reality, these three branches of activities have been coupled closely and managed as a whole up to now, as the Kéage Laboratory of Nuclear Science, so that the histories of these two laboratories are described in common in the following. A few words should be given here about the late Professor Y. Uemura. He had been an important staff member since 1939, when the nuclear science laboratory headed by the late Professor B. Arakatsu was founded in this Institute. He was promoted to a full professor in 1973 and was appointed to the Head of the Nuclear Science Research Facility, but, to our regret, sudden illness attacked him and he died on May 20, 1973. The staff members at present are;

Laboratory of Nuclear Reaction, Dr. T. Yanabu, Dr. N. Fujiwara, M. Sc. T. Ohsawa and Mr. S. Matsuo.

Nuclear Science Research Facility, Dr. H. Takekoshi, Dr. K. Fukunaga and Dr. S. Kakigi.

I. Accelerator Physics

The Kyoto University Cyclotron has been installed in the Nuclear Science Research Facility since 1955 and has been utilized by many researchers in various organizations such as Department of Physics, Institute of Atomic Energy, Research Reactor Institute, Department of Nuclear Engineering, Department of Chemistry of Osaka University and Nara Women's University in cooperation with staff members of the Kéage Laboratory of Nuclear Science. This cyclotron, however, had expired its life span in 1967 and was quite re-newed during 1969 to 1972. The improvement of the cyclotron was pursued under the design work of the staff members and manufactured by the Mitsubishi Heavy Industries, the Fuji Electronic Industrial Co., and by the Shimazu Seisakusho Ltd. Control and operation system of the cyclotron was also renewed. As a result of the improvement, the energy of the accelerated beams became variable and the operation of the cyclotron very stable and easy to handle.

Other topics than the cyclotron improvement were the research work on the extraction of electron beam from the INS Electron Synchrotron. This work was done by the Institute for Nuclear study, Department of Physics of the University of Tokyo, and the Kéage Laboratory of Nuclear Science collaboration. Heavy ion acceleration by the cyclotron was tried also in cooperation with the members of the Department of Nuclear Engineering and founded the heavy ion physics in Japan.

II. Computational Physics

As is described in later section, one of the main items of the Kéage laboratory is the research work on nuclear three body problems. This work necessitates to treat multi-parameter informations. Until 1971, only two parameter data processing was possible by using a two dimentional pulse height analyzer, but this P. H. A. has so little memory capacities to get high resolution nuclear data. In 1972, a mini-computor was installed in the Laboratory and peripheral hard and soft wares were developed in our laboratory to accomplish multi-parameter data processing on line. This on line data processing system could accomodate the needs for three, four, and so on multi-particle production problem and is expected to be very useful in intermediate energy nuclear physics.

III. Other Instrumentations

Fundamental facilities to use the cyclotron beam such as beam transport systems, beam steering magnet, beam momentum analyzing magnet and a broad range magnetic spectrograph were installed until 1966. The design and performances of these instrumentations are reported in 1969. Newly designed and constructed apparata in the decade from 1966 to 1976 are a scattering chamber and a vacuum evaporation device. The scattering chamber is designed to detect particles emitted from the target to any direction in three demensional space and to equip three sets of detectors. Particle-particle correlations not only in the reaction plane but also off the reaction plane could be investigated with this chamber. The vacuum evaporation device is equipped with an electron gun to heat a sample of very high melting point. A thin film of Be, B, and C could be produced with this device and contributed very much to the research work of light nuclei.

IV. Radiations and Matter

Stopping powers of various materials for p, d, and α have been studied continuously by a collaboration from the Nara Women's University and the Kéage Laboratory. Over wide range of Z, from Be to Au, the stopping powers of materials were decided with an accuracy of 0.1% or less and the values are becoming standard ones in the world.

V. Radiation Chemistry

A collaboration from the Institute of Atomic Energy, Department of Chemistry of Osaka University and the Kéage Laboratory has studied continuously the deuteron induced nuclear reactions by radio-chemical technique. Excitation functions of (d,p), (d,2n), (d,α), and other possible type of reactions were obtained simultaneously. Recently, an automatic irradiation chamber followed by a pneumatic tube to convey the irradiated samples to a radio-chemical hood was installed in the Kéage laboratory, and the research of product radio-nuclides of short life times of the order of 10 seconds are under way.

VI. Level Structure and the Excitation Mechanism of Light and Medium Nuclei

Elastic and inelastic scattering of protons, deuterons and alpha particles from the cyclotron by light and medium weight nuclei has been observed to investigate the level structure and the excitation mechanism. Collective excitations were observed obviously by alpha particle inelastic scattering. Optical potential fit was succeeded in the scattering of protons and alpha particles but gave not so good fit for deuteron scattering. Spin-flip states and un-natural parity states were also investigated by means of inelastic scattering of alpha particles. Two particle states were investigated by means of (α, d) and proton inelastic scattering. Core excited state and two step excitation were observed by a (d, p) reaction on light nuclei. Above all, nuclear excitation mechanism seems not so simple that could be explained by a direct or impulse excitation or by a compound process excitation.

VII. Few Nucleon Problems and Three Body Reactions

Search for an alpha cluster in light nuclei has been continued since 1962. Quasi-free scattering peak was seeked in the (p,pα) and (α,2α) reaction by detecting a proton-alpha and alpha-alpha particle correlations. Target nuclei observed were ^{6}Li, ^{7}Li, ^{9}Be, ^{11}B, ^{12}C, ^{16}O, and ^{20}Ne. Conclusions hitherto obtained are that the existence of alpha clusters is clear in ^{6}Li, ^{7}Li, and ^{9}Be. In nuclei heavier than ^{12}C, the existence of alpha cluster is doubtful and the alpha particles emitted are probably due to sequencial decay, that is, emitted from the excited states of the target nuclei. The sequence of these researches led different kinds of research works; one is the few nucleon problem and the other is the nuclear three body reactions. Excited states were investigated for deuterons, ^{6}Li, ^{7}Li, ^{10}B, and ^{12}C and the existence of three-partice (or cluster) states were clarified by observing the break up of target nuclei. On the other hand, kinematically complete experiment of three body problem was found to be very useful to determine the spin and parity of the intermediate particle decaying state. The level structures in the giant resonance region are being investigated by means of particle-particle correlation detection.

VIII. Intermediate Energy Nuclear Physics

In 1962, the Science Council of Japan advised the Japanese Government to establish the Institute for Elementary Particles. This advice took its shape in 1971 as the establishment of the National Institute for High Energy Physics. As T. Yanabu had been one of the committee members to promote the foundation of this Institute, and was interested to develop the field of intermediate and high energy nuclear physics, efforts have been made continuously by Yanabu since 1962 to organize nuclear physicists in Japan for the promotion of intermediate energy nuclear physics. Since then, about 17 workshops had been held in the decade from 1966 to 1976 to study and prepare one's self for the research work which will be performed by using the facilities of the National Institute for High Energy Physics. On the other hand, one of the members of the Laboratory of Nuclear Reaction went to the Orsay Institute for Nuclear Physics and investigated the ^{3}He breakup at 156 MeV, and another member went to the Institute for Nuclear Study, University of Tokyo, and investigated the (e,e'p) reaction at 700 MeV. These activities of the Laboratory of Nuclear Reaction were very effective to attract the attention of Japanese nuclear physicists to the field of intermediate energy nuclear physics.

IX. Theoretical Nuclear Physics

Foundations of nuclear physics has been investigated continuously since 1943, when the Yukawa laboratory was established in this Institute. The history of theoretical researches until 1966 is reported in ref. 3). Here reported are the activities in the decade from 1966 to 1976.

Space-Time Structure of Elementary Particles

Yukawa[4)] proposed in 1966 that the space and time may be composed of elementary domains indivisible any more. This existence of elementary domains was realized by finding that coordinate transformation is a kind of contact transformation. Non local solutions of wave equations were obtained without subsidiary conditions by means of pure algebraic methods.[5)] Also, methods of averaging field variables over elementary domain are being developed on the basis of the theory of measurement.[6)]

Theory of Composite Systems

General problems of composite systems like atoms, molecules, nuclei, and elementary particles, were investigated. The separation of center of mass motion, generators of the Poincare or Galilean group with applications to muonic atoms, high energy electron scattering from nuclei, MT transformation for many photon processes in hydrogen atom, charge transfer reactions in atoms and molecules, and the pion production by proton and other particle capture, are the main items of composite systems studied.[7]

Group Theoretical Foundations of Theoretical Physics

An interesting fact was found that Hausforff's formula in the Lie theory of continuous transformation groups lead to the usual formula in time dependent perturbation theory without the use of analytical methods.[8] We are performing the applications of Hausdorff's formula to thermal neutron scattering by crystal lattice, chiral symmetry in n-dimensional quark model, relativistic wave equations, and others. Group theoretical structure of bi-local field theory was also studied from the standpoint of infinite dimensional representation of the two dimensional Lorentz group.[9]

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