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PLANNING AND IMPLEMENTATION OF NUCLEAR RESEARCH PROGRAMMES†

by

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The development of nuclear physics as well as of the other domains of basic science was the result of the existence of qualified scientists in research institutes and universities in Europe and the United States. After 1945, in view of the success of the Manhattan Project, the Governments of advanced countries decided to invest in the development of scientific research and technology given their proven importance for the economy and national defense. Organisations and agencies were established to stimulate and give financement to science and technology. Economists and experts in science policy usually integrate the directing boards of these agencies. The formulation of basic nuclear research programmes, however, cannot be made without the scientists who practice research and who are the only persons fitted to choose the direction which should take research in their domain of speciality, when research work should be changed, stimulated, postponed or ended.

Scientific advisory committees in the advanced countries are a guarantee of the correctness of scientific planning. In the less developed countries, where the ideas of government agencies for science and technology were spread, the insufficient number of active researchers, the lack of scientific and cultural tradition, the impoverishment of the universities, constitute a threat to a planning and implementation of research programmes which will bear fruit and give a decisive contribution to the advancement of science in these countries.

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1. Introduction: Nuclear physics in the 1930's

Nuclear physics started its really significant development in the decade 1930-1940.

In 1930, W.Pauli wrote his famous letter to a meeting of physicits in which he proposed the existence of the (electronic) neutrino to account for the continuous energy spectrum of electrons in beta-decay. 1932 was the year in which J. Chadwick discovered the neutron and thus showed the reality of the speculation of E.Rutherford and explained the production of penetrating neutral particles when beryllium was bombarded by alpha particles, as investigated by H. Becker and W. Bothe and by F. Joliot and Irene Curie-Joliot. It was at that time that D. Iwanenko and W. Heisenberg independently proposed the neutron and proton composition of atomic nuclei; and in 1933-1934, Francis Perrin and Enrico Fermi formulated the beta-decay theory.

The existence of charge independent nuclear forces established in 1936 and the discovery in the same year of penetrating particles with mass intermediate between those of the electron and the proton, in cosmic rays, gave relevance to the suggestion of H. Yukawa in 1935 of the need of a new field - and new corresponding particles, the mesons - to account for these two results, an account which would be redefined and refined only after 1947.

Finally, in 1939, following the discovery of artificial radioactivity (I. Curie-Joliot and F.Joliot, 1934) and the systematic utilisation by Fermi and his collaborators (1934) of neu -

trons to induce nuclear reactions, there came the discovery of nuclear fission by O. Hahn and F. Strassmann.

In the United States, in 1931, E. Lawrence and S. Livingstone concluded their pioneer project of constructing a small cyclotron. This was the benning of successive programmes of construction of particle accelerators - of various types and of increasing energies and improved intensities for the produced beams of particles - which opened up new horizons to research in nuclear physics and, later, in elementary particle physics.

2. Scientific Research After 1945

With the eclosion of the Second World War (1939-1945), as is well known, the Manhattan Project for the development of the first atomic bombs, in the United States, produced an impact on the caracter of nuclear research and of scientific research in general. The institutionalisation of science, initiated in the XVIIth century in Europe, and which slowly progressed in correlation with the further developments of the industrial revolution, suddenly changed after 1945. Before that year, the criteria for evaluating the strength and for measuring the development of nations were mainly based on their industrial system and the corresponding technical facilities. The intensive research work accomplished during the Second War gave birth to new technologies which now have a great influence on the very political and economic states of nations: nuclear energy, radar, propulsion systems for airplanes, missiles and new biological and medical conquests. After the war, in view of the success of the atomic bomb project - which appeared as an extremely dif - ficult problem to be solved - the governments of the indus - trialised nations adopted the view that investment in sci - entific and techological research could result in the solution of any problem whatsoever. This notion had both good and bad consequences. The good ones were associated to the new and enormous prestige of scientific and tecnological research; the bad effects were those associated with the idea that government officials could choose the directions for the development of science.

3. Scientific Planning: by Technocrats of by Scientists?

As these ideas propagated to the less developed countries, the appearance of experts in science policy, in large numbers, constitutes a difficulty for the scientists of these nations. Indeed, only active scientists or scientific administrators who practiced research, are fitted to choose the direction which research may take, to contribute substantially to the formu - lation and implementation of science policies.

"*The most important skill of a good scientist is the ability to choose the right problem at the right time. It is the scientist who knows where a research idea is ready to bear fruit, when work should be postponed, when the direction should be changed or when it should be given up entirely*"[1].

Now if in the advanced nations, the number of scientists, the high level of research and of the universities, and the cultural and scientific traditions, enormously reduce the danger of a technocratic administration of science, the absence of these qualities in the less developed nations may pose a threat to the formulation - and implementation - of sensible research projects.

Let us succintly look at the development of nuclear science in some countries such as the United States of America and France, Japan and Brazil.

4. The Evolution of Nuclear Research in the United States

In the United States, science policy has been the result of the overlapp of different initiatives: the activities of the universities, university institutes of technology and centers for advanced study in basic research, the research work carried out in scientific and technological laboratories of industrial organisations, agricultural policy, nuclear energy and space activities, the technological initiatives carried out and stimulated by the national defense policy. The tendency in the United States has been to avoid central planning of research through the creation of a Departament of Science and Technology. Instead, a variety of centers of research, have always been stimulated. Moreover, private foundations to promote higher education and research have had an important historical rôle. Only in the year 1950, after five years of debate, did the U.S. Congress approve the creation of the National Science Foundation. In 1951, the President's Science Advisory Committee was created. And in 1957, on the occasion and under the impact of the first Soviet Spountnik, a new post was created in the Administation, namely, the President's Special Assistant for Science and Technology, with the attribution of presiding over the Special Advisory Committee and coordinating the work of the Federal Council for Science and Technology. Scientists and university professors are invited to advise these organismes. And the U.S. Congress disposes of specialised committes to study questions related to science and technology, to write reports and to search for the advice of the scientific community. Specialised agencies exist of course since the end of the Second World War, such as the Atomic Energy Commission which was later absorved into the Department of Energy, the National Aeronautics and Space Administraction and others.

But the important point is that basically the development of science in the United States did not have to wait for these agencies. Immediately after the war a very important group of nuclear physicists was established at the Berkeley campus of the University of California. And as the first cyclotron was built by Lawrence and Livingston, in 1931, these machines began to be constructed at many universities in the United States. The technical and scientific people required for the implementation of these projects - and this is the heart of the question - were available at these institutions. And the cost of these nuclear machines was supported by the grants which came from governmental agencies such as the Atomic Energy Commission which greatly stimulated research. According to Goldwasser [1] the following were the institutions in the U.S. at which cyclotrons blossomed both before and after the war: The Bartoll Institute, Carnegie Institution of Washington, Carnegie Institute of Technology, Columbia University, Cornell University, Harvard University,Massachussets Institute of Technology, Princeton University, Purdue University, Rochester University, University of Chicago, University of Illinois, University of Indiana, University of Michigan and Washington University.

It is clear therefore that developments such as these, at the American Universities and research institutes, constituted a fertile soil for the development of the work of the numerous physicists and other men of science who fled Europe in the decade 1930-1940, and after the war, to establish themselves in the United States and work with their American colleagues.

With the development of newer and bigger accelerators the notion emerged in the U.S. of National Laboratories. As soon as the size, the cost and the scientific and technical personnel for a nuclear machine becomes too large, a single university cannot be able to have the facility - rather many universities unite efforts, financial support and scientific people to house and operate these machines. And the management of a national laboratory must take into account basically the needs of scientists of many universities. To make a national laboratory possible it was necessary to create a university consortium. The first such consortium founded the Brookhaven National Laboratory. Argonne National Laboratory resulted from another consortium, the Associated Midwest Universities. And in 1966 the largest consortium was formed to build and manage the Fermi National Laboratory which houses the largest accelerator (a proton synchrotron at 1000 GeV) - a consortium of more than 50 universities from the United States and Canada. And the experiments and observations by the physicists of these universities are planned and implemented by a Users Group.

Nuclear physics, as you know, gave rise to Particle physics and with the years, ordinary science, little science evolved into big science and the notion came into being of international laboratories such as CERN in Geneva.

5. Nuclear Research in France

In France, where there is a tradition of a centralised Government, centralisation has been predominant for the development of scientific and technological research.

The CNRS, Centre National de la Recherche Scientifique,was created a few years before the Second World War and is nowadays a large organisation which has national laboratories and stimulates research in the universities. Young research men are recruited at the Universities and appointed as scientists of the CNRS working in the CNRS own laboratories or at university laboratories. The French *"Haut Commissariat ã l'Energie Atomique"* was created in 1945 - and develops and stimulates applied nuclear science but also fundamental nuclear and particle physics research.

Both the CNRS and the CEA have close cooperation with the universities and with the advanced schools such as l'Ecole Normale Superieure, l'Ecole Polytechnique, and other so-called "grandes écoles". Accelerators have been built at the Centre d'Etude Nucleaires de Saclay - a Van de Graaff accelerator in 1953, a cyclotron in 1955, a cyclotron with variable energy(1964), a Tandem machine (1968) and an electron linear accelerator(1969). Two national laboratories resulted from the union of efforts by the National Institute of Nuclear Physics and Particle Physics, IN2P3, an organisation belonging to the CNRS, with the Institute of Fundamental Research of the Atomic Energy Commissariat: the Saturne laboratory (1979) and the GANIL, Grand Accelerateur National à Ions lourdes (1983). Other nuclear equipment were built in other laboratories such as the Centre de Recherches Nucleaires de Strasbourg, the Grenoble Institute of Nuclear Sciences, and the Linear Accelerator Laboratory of Orsay.

Both at Saturne and GANIL the research work is carried out by visiting physicists coming from the other universities and they are the guests of a small number of permanent or semi-permanent scientists and technical staff[2].

As in the United States, in France the high quality of research personnel is the essential ingredient in the implementation of the research programmes outlined above. Besides the well-known contribution to physics from de Broglie, there were in the 1930's the activities of men like Langevin, Brillouin, Pierre Weiss, and Proca, as well as the discoveries by the Joliots.

6. Nuclear Research in Japan

In Japan, active research in nuclear physics started in the 1930's a long time after the Meiji reform of 1868 which introduced the teaching of western science in the national universities.

Two laboratories were noted at the Institute of Physical and Chemical Research, RIKKEN, in Tokyo - those of S. Nishikawa and of Y. Nishina. Nishina's laboratory, established in 1931, had experimental nuclear physics facilities, a group of cosmic ray physicists and theoretical physicists - and facilities like a Cockroft - Walton, small and large cyclotrons.

If no report is given of foreign scientists invited to modernise science and the universities, Nishina, however - well-known for instance by his work with Oskar Klein on the Compton effect - spent many years in Europe, in Cambridge, Göttingen and Copenhagen. To RIKKEN, Nishina attracted physicists like S. Kikuchi, S. Tomonoga and S. Sakata.

The other great center of physics research was at Osaka University, founded in 1932 and which organised excellent Faculties of Medicine, of Engineering and of Sciences. This center attracted Kukuchi and Sakata from RIKKEN and Yukawa (in 1933) where he developed the meson theory of nuclear forces with Sakata and Taketani. In the 1940's the influence of RIKKEN and Osaka spread throughout the country and the visit of Japan by Niels Bohr had a great influence on physics research at that time (1937).

In the 1950's, after the extraordinary recovery from the war and the tragedy of the two atomic bombs, new universities were created. In Kyoto emerged the Research Institute for Fundamental Physics in 1953, the Cosmic Ray Observatory at Mount Norikura was created (2800m attitude) in the same year and in Tokyo the Institute for Nuclear Studies was established in 1955, where two cyclotrons were completed in 1957 and 1958 respectively and an electron synchrotron in 1961 (750MeV) which reached 1.3 GeV in 1961.

More recently, in 1971, the National Laboratory for High-Energy Physics, KEK, was created and a proton synchrotron of 12 GeV was built in 1976 and an electron linear accelerator (2.5 GeV) in 1982. The latter, as well as the Kyoto Institute, the Norikura Cosmic Ray Observatory and the Tokyo Institute for Nuclear Study, adopted an organisation similar to the U.S. universities consortia so as to be useful to users from the universities throughout the country. And the Science Council of Japan, which had a man of the stature of S. Tomonaga, a Physics Nobel Prize as its president, has had the prestige and authority to coordinate the research efforts in Japan, to supervise, together with the Japan Atomic Energy Institute, the planning and the implementation of nuclear research programmes [3].

7. Nuclear Research in India

I now come to a brief analysis of the evolution of nuclear research in some developing countries. Of these, I believe, the one which shows a most remarkable development is India. The political stability of this country from independence to our days, the wisdom and appreciation for science and culture on the part of the Indian Chiefs of Government, from Prime Minister Nehru to Prime Minister Gandhi, have been a solid ground for the continuons construction of the scientific and technological edifice. Homi J. Bhabha, a physicist who gave original contributions to the meson theory of nuclear forces, to the theoretical study of cosmic radiation and to elementary particle physics, was able to stimulate and coordinate efforts for the foundation in 1945 of the Tata Institute of Fundamental Research with four main fields of investigation: nuclear physics, cosmic rays, theoretical physics and pure mathematics. The activities in these areas multiplied and diversified and several other disciplines were added to the attention of the Institute, like astrophysics, solid state physics and electronics, computer science and molecular biology. The Institute had a great influence throughout the country and was soon able to give advice and expertise to governmental agencies and to take up special programmes of national relevance.

The Bhabha Atomic Research Centre, under the direction of P. K. Iyengar, develops experimental research in nuclear physics (Van de Graaff accelerators at Trombay, a variable energy cyclotron at Calcutta), in condensed matter physics, biophysics, reactor physics, theoretical physics, seismology and gamma ray astrophysics, plasma physics and materials science besides several other areas of interest to nuclear technology. A Center for Advanced Technology, at Indore is being set-up with activities concentrated on accelerator and laser development programmes.

Let me mention finally only the Saha Institute of Nuclear

Physics at Trombay which develops research work in experimental nuclear physics centered around the Variable Energy Cyclotron; its activities cover also areas in atomic, molecular and solid state physics, plasma physics, theoretical physics and instrumentation among others; and the Indira Gandhi Centre for Atomic Research Kalpakkam dedicated to the development of liquid metal cooled fast breeder reactors [4].

All of these institutes, and other centers of scientific and technological investigation are maintained by the Department of Atomic Energy of the Government of India of which the Atomic Energy Commission is integrated by men of science like Professors M. G.K. Menon, Iyengar and Sreekantan.

8. Nuclear Research in Brazil

What is the situation in Latin America concerning the question of scientific research, and in particular the planning and implementation of research programmes? Usually, the tendency is to compare the countries in Latin America with the advanced nations of Europe and the United States. One easily forgets that actually advanced civilisations - as in Egypt, China, India - were constructed by peoples who inhabited regions of Central and South America, from the central plateau of Mexico to the region of the Andes down to the Argentine land and through the Marajó Island at the delta of the Amazon river in Northern Brazil. "*Fertiles à coup sûr en événements dont nous ignorons à peu près tout, ces siècles engloutis ont heureusement laissé en témoignage des* *oeuvres d'art qui portent la marque des civilisations successives dont elles son issues*" [5]: the Olmèques and the Tolteques, the civilisations of Teotihuacan, of Xochicalco, of Monte Alban and Tula, the Mayas and the Aztecs, in Mexico and Guatemala - the Chibchas, the Mochicas,the Nazca culture, the Wari empire, and around the XVth century, the Inca empire; and in South America, between the VIIth and the XIVth centuries, the Marajoara culture in the delta of the Amazon river.

The invasion of these territories of the Americas by Europeans in the 16th century marked the tragic interruption of the history of these autochtonous civilisations. The scientific and technical progress in Western Europe in the 16th and 17th centuries, was accompanied by an expansion of these countries - in the name of the Church and of Kings, the civilisations of pre-columbian America were subjugated and destroyed, their countries were thus "discovered".

After the establishement of the Portuguese and Spanish "conquistadores" a colonial system was imposed on the native peoples of Central and South America and was responsible for the retardation in the development of science and technology, of culture, in Latin America. The scientific teaching, the experimental investigations which began in Europe and led to the creation of the Academy of Sciences of Paris and of the London Royal Society in the 17th century were absent in the Portuguese and the Spanish kingdoms.

It was only after the establishement of the Portuguese king

João VI in Brazil, who fled Portugal on the occasion of the invasion of this country by Napoleon (1808), that this South American country was open to culture, with the foundation of Medicine Schools, the National Library, the Botanical Garden, the National Museum, the Polytechnical School in Rio de Janeiro and other institutions [6].

It was in the 1930's with the beginning of industrial capitalism that an educational and scientific policy started to be outlined.

Investigation in cosmic rays, nuclear physics and theoretical physics began in 1934 at the Physics Department of the Faculty of Sciences of the University of São Paulo, where two Italian physicists Gleb Wataghin and Giuseppe Occhialini trained theoretical and experimental physicists. Souza Santos, Pompeia and Wataghin discovered the showers of penetrating particles in the cosmic radiation (1940) and Mario Schönberg collaborated with George Gamow in the formulation of the theory of the neutrino collapse of stars (1940). After the war the Brazilian Center for Research in Physics (CBPF) was founded in Rio de Janeiro in 1949 by C.M. G. Lattes, J.Leite Lopes and J. Tiomno, who had come back from Bristol and Princeton. In the late 40's and 50's contributions were given by these physicists to the discovery of pions (1947), to the notion of universal Fermi interaction (1949) and to the prediction of the neutral vector bosons and the unification of electromagnetic forces with weak interactions (1958).

The influence of both institutions spread throughout the country. The National Research Council (CNPq) was created in 1951 and besides stimulating science and technology with grants to laboratories, fellowships in the county and abroad, it had the task of developing all activities related to atomic energy. In 1951 a 25 MeV Betatron, and in 1954 a Van de Graaff accelerator, were concluded at the University of São Paulo and nuclear research was concentrated around these two machines. At the CBPF the nuclear emulsion technique was further developed and studies were also made on cosmic rays in collaboration with the Cosmic Ray Laboratory of the University San Andrés (La Paz), Bolivia,at 5000meters altitude. The move of Guido Beck from Argentine to Rio de Janeiro, the visit of R.P. Feynmam, C.N. Yang, U. Camerini and G. Molière to Rio de Janeiro, of David Bohm and M. Taketani to São Paulo had a great influence on the physics development in the country. In the 1970's new physics institutes were organised at several Universities throughout the country, with investigations on condensed matter physics, nuclear physics, geophysics, cosmic radiation, space and plasma physics, cosmology and particle physics theory.

In 1956 the National Commission of Nuclear Energy was created which set up three Atomic Energy Research Institutes, in São Paulo, Belo Horizonte and Rio de Janeiro each with a research reactor [7].

Nuclear power facilities are being built in cooperation with the Federal Republic of Germany. Technological research work in this domain is developed at the Atomic Energy Research Institutes and at the Center for the Development of Nuclear Technology aiming at developing the nuclear fuel cycle as needed for the nuclear energy reactors.It is however necessary to say that after the petroleum crisis in 1947 and the increase of the foreign debt by the military authoritarian regime in Brazil(1964-1985),delays have been imposed on the accomplishment of the Nuclear Program. And the universities have had less financial support for scientific research.

I have mentioned the political stability of India since the independence, which has been of extreme importance for the development of science and technology in that country.In contrast, the intermittent military dictatorships in Argentina and Brazil have had ill effects on the growth of science in these countries. The quality of the universities during the authoritarian regime was deeply affected in the negative sense as scientists were dismissed from their jobs in scientific institutes and universities - in Argentina, physicists were killed for political reasons.

Usually, in international conferences on science and technology, debates on these questions are avoided. But it is clear that scientific research is not carried out by angels in paradise; the subjacent social conditions are crucial for the development of science and technology anywhere in the world.

9. Conclusions

What about the planning and implementation of nuclear research programmes?

First of all the planning of any scientific research program in any country has to be based on the scientists and technicians available for the implementation of this program. When specialists in a given domain are at work in a given country, programmes arise from their work, from their discussions, from the need they feel to take or to change a certain direction in their work. The construction of cyclotrons in the United States, started in 1931, was the result of ideas of Lawrence, Livingstone and their colleagues, of the development of nuclear physics at that time, of the challenge which they took in initiating a new field of activities, in opening up a new frontier of knowledge. This is valid for any country. If, however, there are not enough specialised personnel in a given field, and if they feel that a new initiative has to be taken in order to achieve a new step forward,then the need for planning a new research program presents itself to them. Some of these scientists may convince financial agencies to support such a planning, and funds must be allocated to study the feasibility of the proposal. Usually, one has to look for laboratories abroad in order to search for a definition of the project and a program is then formulated which will include the draft of scientists and technicians from abroad who will work with those in the host country, the training of young people needed for the implementation of the program. If a nuclear research program is planned for the construction of an accelerator, for developing detection techniques in particle physics, collaboration between laboratories and enterprises from abroad and those in the country will have to be sought. International cooperation is thus important for scientific programmes in all countries.

These are obvious conclusions from the picture we sketched above on the development of nuclear research in some countries such as the United States of America, France, Japan.

In the case of the planning and implementation of nuclear energy research programs, clearly nuclear engineers, economists and other specialists - in heavy machinery, metallurgy, and so on - will have to be at the core of the study.

In any case, creative and competent people in the area of study are of basic importance. I say this because the tendency in some countries like my own is for the appearance of experts in science policy who never practiced any scientific research activity, and who would like to take into their hands the formulation of scientific programmes and projects. And who might require from scientists asking for financial aid for their research work that they state the finality of this work, the goal to be attained, its practical significance. Now, if applied science has a given direction, pure science usually sprouts from speculations, from questions that scientists pose to themselves and which arise from their own work. Quantum mechanics did not arise from technocratic projects imposed to physicists in the twenties and early thirties in Europe. Physicists of the physics institutes in Göttingen, Berlin and Munich, in Leipzig and Holland, in Zürich and Rome, in Cambridge, in Paris as in Japan, the Soviet Union, the U.S.A. were in strong interaction among themselves and converged to the Copenhagen Institute where was Niels Bohr. After 1945, science grew tremendously and financial support for so many programmes in some countries need some study of feasibility, some coordination of the activities in different laboratories, to avoid excessive overlaps; but some common interest among laboratories must exist so that scientists may work together, exchange ideas, inspire themselves in other colleagues - and inspire them.

In this paper I have discussed basic nuclear developments, and it would be most desirable that the International Atomic Energy Agency had a new role in stimulating again this field. For after 30 years of development of the conventional nuclear energy since the 1955 International Conference on the Peaceful Uses of Atomic Energy, it would be of the greatest interest for all,that basic research in the field of pure nuclear and particle physics and in the domain of fusion were specially stimulated.

Besides a renewed effort of technological research on rigorously safe nuclear reactors investigation must be carried out on fusion, in particular on the recent advances on muon catalysis of fusion.

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