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FUNDAMENTAL SCIENCE AND HARD TIMES

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A serious threat has come over the fundamental science in the former republics of the USSR and some other Member States of the JINR. And this science should be protected. The aim of this article, which does not pretend for the originality, is to present the arguments for the necessity of this science including those expressed by the other authors, and object to the"arguments" put forward to approve of the process of its reducing.

As an example I will consider Particle Physics (also called High Energy Physics)-the most fundamental part of modern physics.

The task of the fundamental science (sometimes it is called "pure science") is to penetrate the Nature, her main principles and laws.

The task of the applied science is to solve concrete problems connected with bare necessities of the society. As a rule, the applied science uses the fruit "grown" by the fundamental science. Many experts have devoted their articles to the importance of the fundamental science, high energy physics in particular, for the society. First of all, it is of great value for those countries where this science is being developed at the present moment and,to some extent, for all the mankind.

I would like to mention some of these articles, whose separate statements and examples I would quote: L.M.Lederman "The Value of Fundamental Science"/1/, D.I. Blokhintsev "Relationship of the Fundamental and Applied Sciences"/2/, V.F. Weisskopf "In Defence of High Energy Physics"/3/, M.G.N.Hine "Financing High Energy Physics"/4/ M.A.Markov "The Future of Science"/5/.

At first, we shall consider the importance of the fundamental research from the practical point of view: how it influences the material sphere of our life.

To simplify this , one can say that the fundamental science of nowadays determines the applied science for tomorrow and , in its turn, the applied science inspirates

the development of technique and technology for the day after tomorrow. Thus, the fundamental science is the basis for the technical progress and then,-material sphere.

To be more concrete, I would like to speak about physics.

The historical experience has shown that all the significant discoveries in physics beginning from Galilei and even Arkhimedes times till now, have led to the appearance of principally new fields of technique sooner or later. The way of the less significant discoveries into practice is more complicated to follow but, in principle, it is analogous. It is also possible "to solve the inverted task": to start from the main technical innovations back to their roots. And we shall see that at the very beginning,usually, the discoveries of the fundamental science took place.Some classical examples.

Faraday's discovery of the electromagnetic induction rose the appearance of the electrotechnique. The theoretical research of Maxwell and Hertz became the grounds of the radio technique. Quantum physics made possible creating semiconducting electronics and lasers.

The investigations of the atomic nuclei performed in the traditions of "pure science", started the conquering of the atomic energy. The enumeration list could be easily continued.

One more of the less significant but characteristic examples. The creation of the navigation system using a number of satellites over different points of the Earth, required to take into consideration the relations of the relativity theory to compare the time in the satellites moving relatively each other. At first, these relations were not taken into account and that is why the system did not start working.

The scientific -technical revolution of the second part of the 20-th century became possible due to the fast development of the fundamental science and, mainly, physics in the first half of our century.

It is not accidental that the wise Alfred Nobel, an applied chemist and prosperous manager, arranged prizes for the outstanding achievements especially in the fundamental sciences.

There are also gradations in the fundamental sciences themselves on the level of their "fundamentality": whether this research studies and defines the main laws of Nature or explains phenomena based on the known principle laws.

V. Weisskopf called the first type of the research "intensive" and the second- "extensive".

Among the examples of the "extensive" fields of science he calls the Solid State Physics and Plasma Physics. At the present time the High Energy Physics is predominantly an "intensive" science. Earlier in our century electrodynamics and relativity, quantum theory of the atom and nuclear physics were the developing steps of the "intensive " science, but within the time they became more and more "extensive".

High Energy Physics is, first of all, the physics of the microworld, a science on structure and properties of matter at the subnuclear level, on the smallest "bricks" our Universe consists of,and their interactions. And the simpler the system - the more general laws determines its properties; so Particle Physics is at the same time a science on the more general principles and laws of Nature, a global branch of science. That is why its influence on many other natural sciences is deep and constantly increasing. In particular, the connection of Particle Physics and Cosmology to create the general picture of the origin and evolution of the Universe, has become natural. One of many examples of interactions between micro and macro cosmos sciences is the CP-violation, a violation phenomenon in one of the world symmetries, discovered and researched at the High Energy accelerators. This phenomenon, according to Sakharov's

Hypothesis, could explain why our Universe consists (at least, mainly) of particles but not anti-particles. If there were no CP-violations our world would be quite different: there would be the equal number of particles and anti-particles annihilating with each other but there would be hardly a chance not only for us but also for any complicated form of matter to exist.

Within several decades of its existence Particle Physics has achieved amusing results and success. First of all, it penetrated deep into the matter to the level of protons and neutrons(atoms consist of),mesons(born in high energy nuclear interactions) and numerous excited states of these particles. Then one managed to penetrate even deeper to quite a new qualitative level. The more elementary constituents of the matter were discovered - the so-called quarks which construct protons, neutrons, mesons and their excited states with the help of the "gluing" particles-gluons.

The discovery of quarks, the proof of their existence and properties is more than surprising because the quarks have turned out to be unobservable in the free state.

Nowadays Particle Physics is a strict and logical branch of science which allowed one to make numerous approved predictions. In the theory and experiments it is intensively moving forward to disclose and understand the deepest and universal laws of Nature. "The level of this science,- said Academician L.B.Okun,-determines the understanding level of the world surrounding us and the level of intellectual maturity of mankind."/6/

"Intensive" research represents the frontier of science. When these researches achieve a rather high level of development, they lead to the appearance of new fields of "extensive" research which, in their turn, determine the new directions of the applied science.

I would like to emphasize one peculiarity in the process of using the discoveries of the fundamental science in practice. The scientists who made these discoveries were performing their research due to the "pure" scientific interests and intellectual desire to knowledge characteristic for the people who often even did not imagine the possible practical application of the results of their work.

A classical example: in 1933 Rutherford said: "Anyone who expects a source of power from these atoms is talking moonshine." Six years later the fission of nuclei was discovered and then three years after-the first atom reactor started working.

But still, what will the High Energy Physics be able to bring to practice in future?

The most important among the possible applied results of its further development is creation of new methods to get the energy having the higher efficiency than those based on the heavy nuclei fission and thermonuclear fusion reactions(less then 1% of the full energy of the substance, the so-called, rest energy, defined with the known relation $E=mc^2$, is released in the fusion reactions). In principle, such natural processes where the rest energy goes out fully, are possible. It is even impossible to imagine practical consequences of the discovery and usage of these processes.

Will the mankind be able to create energy sources more efficient than the thermonuclear synthesis? The rapid development of science in the XX-th century let us hope that in the long run this task will be solved. The approaches to its solution presented in the article of L.Lederman, are still quite problematic. Among them there is the usage of annihilation process of matter and anti-matter, "Rubakov's effect"- catalytic increase of proton decay (which is theoretically quite possible but has not been observed yet),

with magnetic monopoles (hypothetical particles not observed yet), etc.

But, probably, this task will be solved with a quite new approach we cannot imagine now. In any case, it is no doubt that if these super sources of energy are created it will happen only due to the development of High Energy Physics in the result of penetration into the microworld level which is deeper than it can be reached with Nuclear Physics. And now the direct applied usage of the Particle Physics is not significant(we can compare it with the usage of the Atom Nuclei Physics in the 20-es).

Besides the direct usage of the results of the fundamental science it influences practice indirectly. To count it and, especially, quantitatively, is much more difficult though it is rather substantial. The requirements of the fundamental science rise the necessity to develop many applied researches, new technique and technologies, i.e., stimulate technical progress. For example, High Energy Physics requires to create the more advanced accelerators, particle detectors, reception and processing of a large information volume. Naturally, vacuum technique, cryogenics, super conducting technique, specialized electronics are developing, correspondingly, etc. Strong mutual influence between Particle Physics and technical progress is evidently demonstrated, in particular, with regular international conferences "Advanced Technologies and Particle Physics" and "Industry and Super Accelerator SSC, which gather physicists and representatives of firms developing technologies for the scientific researches.

A large number of technical developments aimed, at first, for the needs of High Energy Physics and stimulated with it, further finds the application in the other fields and gives a good economic effect. As an example, L.Lederman enumerates different practical usage of the accelerators created primarily for the fundamental science, including radiated isotope production for the medicine, swelling therapeutics, ion implantation into semiconductors at circuit production, synchrotron radiation generation, having, in its turn, many practical application, etc. L.Lederman also shows the necessity to account secondary effects from secondary effects. Pure profits from the industrial activity inspirated with these applied results, are estimated in billions of dollars a year.

But evaluating the role of the fundamental science, especially nowadays, we should not be satisfied with its possible practical implementation. This science is the unseparable part and one of the basis of civilization, intellectual richness of the modern society and its general culture.

Especially the fundamental researches create the very basis of knowledge used by specialists of different concrete fields.

Within the time the prominent discoveries of the fundamental science, at first, known and understandable to a narrow circle of scientists, become the subject of study at schools and in a simplified way are included into the mental outlook of a modern person forming.his imagination about the surrounding world(now you would not find a person in the civilized world who has never heard about atoms, atom nuclei, electrons, etc., or believes the Sun turning round the Earth).

Penetrating the mysteries of the world construction and its principle laws, understanding the "origin of things" which the best intellectuals have tried to know since the ancient times, does not only develop but also makes a revolution in the human thinking (for example, makes possible to understand phenomena we cannot either observe directly or even simply imagine - such as wave properties of particles in quantum mechanics or twin paradox in the relativity theory).

Getting to know the world we live in, leads to understanding of our place in this world and helps to realize the sense of life.

The role of the fundamental science is also substantial in the struggle with the false-science which, unfortunately, actively finds its place in the consciousness of wide layers of the population(and mass media promote this process).

But the value of the science is not only in the results but also in the process of the scientific activity itself.

The intellectual attractiveness of the fundamental science involves a considerable part of the most gifted people into the scientific work (and the absence of the possibility to be occupied with this science leads to unavoidable "brain-drain" and, moreover, the best specialists).

There is the back effect: the more intensive fundamental researches are held in the country-the more number of young people choose science as their future occupation providing the increase of the most important resource-intellectual.

The role of the fundamental science is significant to maintain the high intellectual level of the whole scientific community, it influences "all the science" and the higher education.

If the results of the applied researches could become "the secret of the firm"-the results of the fundamental research belong to the whole mankind and become the subject of the wide international intellectual exchange.

The laws of Nature are equal for everybody, the fundamental sciences are over national interests and that is why they unite people from different countries with strange ideologies and religions (it is one of the differences of science from religion and ideology which unite only their adherents but very often make an opposition to those who confess another religion or support a strange ideology).

The modern fundamental science just cannot exist without intensive international ties. That is why the role of this science is so high in creating the international community of scientists- and,in its turn, this community influences greatly the general development of the international relations and cooperation between different states and peoples.

The factor which promotes the development of the international scientific cooperation is as follows: Some directions of the fundamental research require significant material resources and participation of a great number of specialists with high qualification, but separate countries cannot afford it.

So, the efforts of many countries should be united and international collaborations appear. This tendency is demonstrated in developing High Energy Physics which requires the more complicated and expensive experimental set-ups of the industrial range. That is why especially for the High Energy Physics research, the first (and still the only ones) large international scientific centres: Centre of European Research of Nuclei (CERN) in Geneva and the Joint Institute for Nuclear Research in Dubna, were organized.

The fundamental science is a great spiritual value, the factor of moral improvement, which puts forward the aspiration to know the world over mercantile interests (it is willingly used and the scientists are paid less for the fundamental research than for any labour not so intensive intellectually, i.e., as if some kind of tax exists for the chance to be occupied in the field of "pure science", for the important component of "high life" and for the intellectual it means to participate in the process of knowing the world).

The fundamental science is a necessary (unfortunately, it is not sufficient) condition for the intellectual health of the society.

And if the fundamental research is not performed in the country, it is the sign of intellectual misery.

Everything mentioned above can be concluded in the following way: the fundamental science is one of the basic and important conditions of progress in material, intellectual and spiritual life of the mankind.

Let us compare the use brought by the fundamental science with the expenses for it.

A curious estimation is given in the articles by Weisskopf and Hine mentioned above: from the time of Arkhimedes till 1965 when those articles were written, all the expenses for the fundamental science approximately reached the cost of the ten-days-world-industry-product of the level of 1965(that is less than the cost of the industrial production increase of the appointed year). It is the impressing result which demonstrates, besides all the rest, the unusual, I would rather say,-incredible efficiency of investments into the fundamental science.

Within the past decades the fundamental sciences have become considerably more expensive due to the necessity to create the advanced and ,it means, -more expensive set-ups and equipment. But still, the total expenses for these researches compose only several percent of the expenses for the applied sciences and less than one percent in the total budget of the developed countries. As an example I would like to mention the budget of the Academy of Sciences of the former USSR(covering, to tell the truth, not all the fundamental research in the country). Within the last years it formed ≈4% of the total department-science budget, i.e., including mainly applied scientific-research institutions.

According to Lederman's estimate, in the USA the share of the fundamental science was only 5% of the sum for the applied research and that was only 0,5% of all the expenses of the total state budget.

It is unnecessary to mention that in the USA, as well as in the former Soviet Union, the expenses for the fundamental science were too small to be compared with the military expenses.

As an illustration I would stress that the year budget of CERN was by several times smaller than the cost of one atom submarine which every of these states had about one hundred .

At the same time a considerable part of the total product produced by the modern society (according to some estimates till 1/3) has the basis, or is the direct usage of the fundamental science results, or their indirect influence. Thus, the expenses for the fundamental science are, finally, paid back many times.

Nevertheless, the question on financing of the fundamental science rises again and again. It is evident that these researches(in comparison with the applied ones) cannot be self-financed: their final product does not belong to the sphere of commerce. That is why the fundamental science can exist only in the case if the expenses(at least, the main ones) are provided by the state.

In the developed countries where the economic situation is favourable, the financial questions for the fundamental sciences, are solved more or less satisfactorily, though, certainly, there are also problems there and different ones for large and small countries. But very often in the states who suffer from economic hardships, particular in the Eastern Europe and the former republics of the Soviet Union, the question of economy reducing the expenses for the fundamental research arises.

One of the "arguments" against the fundamental science financing, sounds, somehow, as follows: " Let the richer countries be occupied with the fundamental sciences and we shall use the results of their research."

But the fundamental science cannot exist only due to the "import". This shows , in particular, the example of some developing countries who even with high income, are behind in the development of science with all the consequences of this lag. To accept and use the research results of the others , to choose and select the substantial from the great flow of information and publications, make people acquainted with these achievements, first of all, the youth; to be in the course of new and advanced data - all this can be done only by specialists, i.e., people who are occupied with the fundamental science. If these researches are not performed -who will fulfill this work? All the most qualified specialists would prefer to go abroad and try to find the better application. The young people who could have become the fame of science of their country, will choose another road in life far from the problems of "great science".

The scientific potential of any country is created not for years -but decades of years. There should be scholars and teachers who should prepare the future generations of scientists. There must be scientific schools and traditions, a special atmosphere where young people will have an opportunity to feel the taste of modern science and accept its appeal.

And surely, there must be the corresponding infrastructure - laboratories, chairs, institutes.

In the countries where all this has already been created, the situation in the field of science differs substantially from the countries who will have to do this. Of course, the politics towards science in these countries should be different: in the first case -it is necessary to create the scientific potential, in the second-at least to preserve what they have already done (it is much easier). It is evident that the economy of the share of the percent planned in the budget for the fundamental science, would never solve even a single economic problem. But the negative consequences of this "economy" cannot be measured, besides, they are lasting and invertable: the scientific potential is sure to be lost. The science would fade away, at least, till the next generation.

There are some other proposals on the economy due to the fundamental sciences: to finance only some of them which do not require large expenses or those-close to the applied science,- having the perspective to be implemented in practice. Such kinds of proposals, unfortunately, sound on behalf of the scientists who wish to keep or even increase assignations for their "own" direction of research in this way. The suggestions to save money due to the High Energy Physics because it requires more money than many other fundamental sciences, are heard very often. Besides, High Energy Physics is blamed in "uselessness for practice",though it is quite evident that the frontier of science cannot bring its fruit to practice immediately: their turn will come further.

Meanwhile, by its origin the fundamental science should develop in wide range, its branches are closely interlaced with each other. For example, High Energy Physics is unbreakably connected with Nuclear Physics, Astrophysics and Cosmology, with all the theoretical physics, etc. It is impossible to "close" for some period of time even one of the fundamental sciences without damage for many other sciences. That is why even in small countries who cannot participate in the research very actively in all parts of the fundamental sciences, it is necessary to concentrate the efforts, at least, on some of them and still preserve the minimum number of scientists for the main directions of science. These specialists could be the connecting chain with the world science and let the representatives of the other fields of science and youth know the latest achievements in this field.

Unreasonable are the "arithmetics arguments" while discussing the questions on financing the science: the priority in financing should be given to those fields and directions of research where the more number of scientists could work at the equal expenses. But the task of science is not to provide job to all the scientists and the priorities in financing must correspond, first of all, to the importance of the scientific results being received or

expected*. It is necessary to realize that reducing of resources for fundamental science, general or separate, breaks one of the basis which composes the country progress.

Reducing of the fundamental science is a sign of despair, distrust in perspective and a chance for way out of the country from the crisis spread over it. According to the expression of Hine, the reducing of the fundamental science is " a slow but sure intellectual suicide" for the country.

In the years of a horrible blockade in Leningrad during the II World War, when hundreds of thousands of people died of starvation, the researchers of the Plants Institute, organized by N.I.Vavilov, saved the unique collection of corns being kept at the Institute, but they did not allow themselves to use it for to save their own lives. At the other institute in Leningrad during the blockade, the unique monocrystals of sugar, especially grown for physics experiments, were also preserved.

These heroic deeds for the sake of Science should serve the example for us. Though our life is rather hard but we do not yet die of starvation.

The economy of means aimed for the fundamental science is unavoidable in the present conditions. But it should be performed extremely carefully not to break the basis of existence of this science: there is the minimum of the necessary assignations; if lower-the chain reaction of destroy would start. The staff of scientists must be preserved: the young ones who have just begun and the experienced, leading specialists, besides, the minimum necessary

*At the same time besides the scientific significance, the number scientific groups interested in the presented experiment should taken into account inside one research field while determining the priority of separate experiments.

infrastructure, should be saved as well for the sake of attractiveness of the fundamental science to keep the gifted youth for this science would not exhaust.

The financial problem is a key problem now to save the fundamental science in the former republics of the USSR, as well as in the former socialist countries of the Eastern Europe.

At the same time it is necessary to provide the most reasonable spending of the means aimed for this science.

In particular, if to speak about the High Energy Physics, it is not reasonable, for example, to build new accelerators in the period of economic hardships; those which already exist, or are being built, could be quite enough at the wise organization of their usage because the international labour distribution of scientists let work using the present accelerators of the high class in the world.

The critical situation in our countries requires the quickest reorganization of the scientific research and sufficient increase of their efficiency.

In this connection I would like to attract the attention to the experience of the research organization on High Energy Physics where the international collaborations and scientific centres are the most popular and provide to unite financial, material and intellectual resources of different countries. This experience is worthy spreading and especially actual in our countries at the present moment.

The break-down of the union system of the fundamental research organization in the former Soviet Union, requires to create the necessary international systems covering the new built sovereign states to preserve the breaking scientific ties. It is necessary to take into account that in small countries with limited resources, the possibility for the scientists to participate in international collaborations is the most important condition for the fundamental science to exist and develop. And physics research in

national frames , exaggeration of the national scientific institutes for the sake of "prestige", will inevitably lead to the decrease of research level and their efficiency.

In science like in politics, the super "sovereignization" is followed by many negative consequences.

In these conditions the special importance and support should be paid and, really, it is worthy supporting,-to the only centre of the international scientific research of our countries- the JOINT INSTITUTE FOR NUCLEAR RESEARCH in Dubna.

Scientific programs of the JINR created primarily (like CERN) to research high energy physics, now cover experimental research as well as theoretical ones on the problems of nuclear physics of low and middle energies and physics of condensed matters. Some applied research is also performed at the Institute.

The wide spectrum of the scientific tasks being solved at the JINR is a source of some problems inside the Institute, but at the same time rises its role as the centre of international unity of scientists: the Member States have the choice of scientific fields they are interested in.

Recently many countries -the former republics of the Soviet Union,in this account we can find the states which are not the members of the Commonwealth (science unites better than the politics), have become new Member States of the JINR.

There are many international collaborations on the basis of the JINR.

At the same time the Dubna institute has stable ties with the number of scientific centres in the West and substantially helps the scientists from the Member States to come into contact with the international collaborations together with the scientists from the countries,where the scientific level is higher.

The creation of the international collaborations to research in different fields of science will help them to survive in the present hard times.

Let us try to conclude in short.

We should realize how real the danger of ruin is over our fundamental science, intellectual catastrophe which inevitably would bring the degradation of the whole society.

In spite of economic, political and other difficulties, it is necessary to do everything possible to save our science created by labour and talents of many generations. Otherwise, very soon we shall be far behind the world civilization.

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Фундаментальная наука и трудные времена

Обсуждается значение фундаментальной науки и ее положение в бывших социалистических странах. Подчеркивается необходимость международного сотрудничества в области фундаментальной науки для ее выживания в этих странах.

Работа выполнена в Лаборатории сверхвысоких энергий ОИЯИ.

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Fundamental Science and Hard Times

The significance of the fundamental science and its hardships in the former socialist world are discussed in this paper. The necessity of international cooperation in the field of fundamental sciences in emphasized for the sake of its survival in these countries.

The investigation has been performed at the Laboratory of Superhigh Energies, JINR.

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