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UKRAINE — CERN: THE WAY TO COOPERATION

Introduction. *The European Organization for Nuclear Research (CERN) is the world largest laboratory for high-energy physics and a platform for creative relationship between researchers from different countries.*

Problem Statement. *The development of international scientific cooperation, in particular, the creation of conditions for expanding the participation of Ukrainian researchers in carrying out the largest physical experiments on nuclear physics, gaining new knowledge and facilitating the innovation processes in Ukraine.*

Purpose. *To analyze factors that facilitate the development of cooperation between Ukrainian researchers and CERN and to outline prospects for the future.*

Materials and Methods. *Analysis of CERN research activities in the context of international cooperation and outlook of CERN international research projects in high-energy physics.*

Results. *The way of cooperation with Ukraine from the very beginning of the CERN creation to the signature of the Agreement on Associate Membership of Ukraine in CERN has been analyzed. Examples of the positive impact of cooperation with CERN on innovation processes in Ukraine, in particular, in the field of the development and production of new high-tech materials, which are crucially important for implementing state-of-the-art experiments in high-energy physics have been considered. The associate membership has allowed Ukrainian researchers to participate more actively in the study of the global physical phenomena of the universe in the most advanced experimental laboratory and engineers and technicians to master the cutting-edge innovative technologies, including informational and medical ones. Prospects of the further cooperation have been outlined.*

Conclusions. *Cooperation with CERN enables Ukraine to take advantage of CERN mission, one of the main tasks of which is the cohesion of people from different countries and cultures through science. Teachers, students, and schoolchildren of Ukraine have got new opportunities to work with the state-of-the-art methods, modern equipment, and innovative approaches in the training of highly qualified specialists in physics and related fields of science and technology.*

Keywords: researches, high energy physics, and cooperation.

CERN is the European Organization for Nuclear Research, the world's largest high-energy physics laboratory. It is located on the border of Switzerland and France, near Geneva. The creation of this pan-European organization for physical experimental research was initiated by remarkable scientists of the first half of the twentieth century, including Pierre Auger, Niels Bohr, Louis de Broglie, and others. Their suggestion was based on the idea of international cooperation for the peaceful use of the atom. In December 1949, in Lausanne (Switzerland), at the European Cultural Conference, Louis de Broglie formally proposed the creation of a European laboratory for physical experimental research in which it would be possible to carry out large-scale researches that could not be

realized in one particular country. In June of the next year, the American Nobel Prize winner Isidore Rabi, at the 5th UNESCO General Conference (Florence, Italy) made the following resolution, "To authorize UNESCO to support the establishment of regional research laboratories to enhance international scientific cooperation". As a result of numerous efforts of leading scientists, at the UNESCO Intergovernmental Meeting in Paris, in December 1951, it was decided to establish the European Council for Nuclear Research, and, within two months, 11 European countries signed an agreement establishing a temporary council. Then, the abbreviation of the Council name in French, CERN, appeared. At the third CERN session, in October 1952, Geneva (Switzerland) was chosen as the location of the future laboratory. In June 1953, a referendum was held in the Canton of Geneva, when more than 60% of the voting participants agreed to the establishment of the research center in their territory. The agreement on the establishment of the center was signed in July 1953 and gradually ratified by the 12 European countries. In September 1954, a new governing body, the Council of the European Organization for Nuclear Research, was formed instead of abolished temporary European Council, formed in 1952, but the CERN abbreviation remained and stroke root in the new organization. The date of the CERN Council creation is September 29, 1954 that is considered CERN's birthday. Other European states gradually joined the organization, in particular, after the collapse of the Soviet Union, the Eastern European countries became its members. In 2010, CERN's constitution was amended and non-European states could join the organization. In 2014, the first non-European country, Israel, joined CERN. Today, 22 countries are full members of the organization, 7 countries are associate members, and several states and international organizations have the CERN observer status that gives them the right to participate in CERN meetings and research. Among other countries, Japan, the United States, Russia, UNESCO, the Joint Institute for Nuclear Research (JINR) are registered as observers. This means, since 2014 CERN can be considered not only a European but also a world research institution [1].

In 65 years, CERN has become one of the most renowned world high energy physics research centers. CERN's operations are funded by the Member States, with an institution budget reaching over 1.2 billion Swiss francs, as of 2018, which ensures not only paying high salaries to researchers, but also building state-of-the-art accelerator complexes for particle physics experiments.

The history of CERN accelerators began in 1957 with a modest, even for that time, 600-MeV synchrocyclotron (SC). Two years after the launch of SC, a 28 GeV proton synchrotron (PS) started to operate. Based on the proton synchrotron, in the early 1970s, the world's first proton intersecting storage rings (ISR) collider was created. In June 1976, a super-proton synchrotron (SPS) with acceleration of protons up to 400 GeV was launched. After SPS upgrade, the researchers obtained proton-antiproton collisions at an energy of 540 GeV, in the center-of-mass system, which was sufficient to detect W- and Z-bosons. For this discovery, Simon van der Meyer and Carlo Rubbia were awarded the Nobel Prize.

The next stage in the development of CERN accelerator technology was the large electron positron collider (LEP) for precise measurement of various characteristics of the Standard Model of Particle Physics. In the 1990s, it became clear that the LEP capacity for detecting the Higgs boson was not enough and CERN started to create the Large Hadron Collider (LHC) using a LEP a 27 km long circular underground tunnel. The large hadron proton-proton collider was commissioned in 2008, and the projected energy of 14 TeV in the center-of-mass system was reached in 2015. There are 4 major detectors in four underground collider mines, 2 of which are multi-purpose ones. A series of large-scale collaborative experiments has been conducted using the collider. Multipurpose experiments have been carried out by ATLAS and CMS collaborations.

The phenomena of heavy quark physics have been studied on a specialized LHCb detector; those of physics of heavy ions and quark-gluon plasma have been carried out in the framework of the ALICE experiment. A series of smaller-scale, but important for modern physics experiments, in particular, TOTEM (measurement of the complete intersection of diffraction processes) and LHCf (a special-purpose Large Hadron Collider experiment for astroparticle (cosmic ray) physics designed to study the particles generated in the "forward" region of collisions, those almost directly in line with the colliding proton beams) has been carried out there as well.

Research is being carried out to develop an electron-positron compact linear collider to explore the next energy frontier of 3 TeV (CLIC). This project is being implemented by CERN in close collaboration with research institutions in 36 countries. CERN's strategic plans are to create a super-large collider with an underground proton accelerator using 100 km long superconducting magnets and an energy up to 150 TeV, which is almost an order of magnitude higher than the LHC. To develop a conceptual design of the future collider, CERN has created an FCC (Future Circular Collider) collaboration that already has counted over 1300 participants from 150 universities, research institutes, and industrial corporations. This year, in January, the FCC project has submitted a conceptual design report that outlines various options for the future large circular collider, possible technical solutions, cost estimate, and implementation schedules [2].

Cutting-edge research equipment and energetic creative work of all staff have contributed to the fact that, a series of significant discoveries, including the determination of the number of types of neutrino, the creation of the first antimatter atoms, and the discovery of new elementary particles (tetra-quark and penta-quark) have been made in CERN experiments. The most resonant event has been the discovery and further confirmation in the ATLAS and CMS experiments of a 125—126 GeV boson later identified as the Higgs boson, which was announced on July 4, 2012.

In addition to the mentioned remarkable breakthroughs in fundamental physics, CERN is also famous for the fact that in 1989, within its walls, there was suggested an idea of the Worldwide Web known as the Internet. Initially, the procedure for document interfacing was designed to facilitate the exchange of information between groups of researchers conducting large-scale experiments and used only within the organization's internal computer network. Later, having modified a number of important computer segments and developed appropriate protocols, in 1993, CERN reported that the Worldwide Web, or the Internet, would be freely accessible to all users. CERN has also become one of the hubs for developing the new Grid computer network technology for storing and processing vast amounts of information. The special collider-related department — LHC Computing Grid is part of a major Grid, an EGEE project that takes advantages of network technology to process large volumes of information in large-scale scholarly research. A relatively new area of research is medical physics that deals with the peculiarities of the influence of radiation processes on biological environments and the development of hadron therapy centers using CERN accelerator technologies.

The mentioned examples of CERN's activities demonstrate why all advanced economies, R&D institutions, and eminent physicists seek to collaborate with CERN.

Today, CERN employs 2,500 researchers, 1,800 technical staff, and 13,000 users from over 100 countries.

In addition to research and development, CERN contributes to the training of researchers and engineers of the future, places great emphasis on promoting science and the ideas of peace and commonwealth via the cohesion of people from different countries and cultures through scientific collaboration.

The first facts of the cooperation between Ukrainian physicists and CERN are dated almost to

the very beginning of the CERN experiments in particle physics. As early as in 1958, Dmitri Volkov, a young scientist who had just graduated from the M. Gorky Kharkiv State University (nowadays, Karazin KhNU), later a prominent theoretical physicist, one of the authors of supersymmetry and its application to aspects of the general theory of relativity — supergravity, was sent to CERN. In 1961 and 1962, he studied both theoretically and experimentally the statistics of known elementary particles, as well as hypothetical particles — quarks. In 1965, Dmitri Volkov had a two-month internship at CERN, during which he was studying the application of higher symmetries to the strong interactions between elementary particles [3]. The collaboration got especially intensified after the signing of the first cooperation agreement between the former Soviet Union and CERN, in 1967 [4]. Delegations of Soviet nuclear physicists, including Ukrainian researchers, often visited the European Nuclear Research Organization that was rapidly developing and actively commissioning more and more powerful particle accelerators. In particular, at the invitation of CERN's then-director Leon van Hove, Dmitri Volkov was working at the CERN Theoretical Department in 1976—1977, where he was doing research on the relationship between different concepts of supergravity theory. Here, also, the point that should be mentioned is the DELPHI and L3 experiments on the LEP electron positron collider for precision measurements of various characteristics of the Standard Model of Particle Physics.

It should be noted that for Ukraine having no sovereignty that time, Ukrainian researchers who cooperated with CERN represented the Soviet Union or other countries or their universities.

The situation started to change after an agreement on the further development of scientific and technical cooperation in the field of high energy physics was signed in April 1993 between the State Committee of Ukraine for Science and Technology (represented by S. Ryabchenko) and the European Organization for Nuclear Research (represented by C. Rubbia). The agreement stated that, since from the very beginning of its activities, CERN had been working closely with R&D organizations of the former USSR, including with those located in the territory of Ukraine, and given the desire of CERN to strengthen and to develop cooperation with countries that were not members of CERN, but with whom the Organization had been long and successfully partnering, the parties agreed to create the conditions necessary for continuing and developing the scientific and technical cooperation on a partnership basis. Cooperation is mainly based on research projects for which specific agreements are signed. Physicists, engineers, and specialized technical personnel from Ukraine may participate in CERN research projects in the field of experimental and theoretical physics, accelerator and detector design, as well as other related fields of science and technology, under the terms and conditions of the abovementioned agreements. Ukraine's contribution to a specific CERN project is to provide staff, materials and equipment, funding, or combination thereof. The Government of Ukraine supports such major CERN programs and projects as, for example, the Large Hadron Collider in the LEP tunnel, which the institutions of Ukraine are interested in [5].

The conclusion of the abovementioned agreement opened up many opportunities for Ukrainian researchers, including the opportunity to work with CERN directly, without intermediary of other organizations and countries. This was the period when, after ten years of consultations and debates, CERN finally approved the idea of creating the Large Hadron Collider (LHC) and started intensive work on the design and search of materials suitable for the creation of detectors for high energy physics experiments. Originally, four experiments (ALICE, ATLAS, CMS, LHCb) were foreseen and later three ones (LHCf, TOTEM and MoEDAL) were added.

At that time, several leading Ukrainian R&D institutions for physics and material science, as well as universities, had had some experience in international experiments on particle physics. In 1988, the R&D Center "Institute of Single Crys-

Fig. 1. The first lead tungstate crystals delivered to CERN [8]

tals" (Kharkiv), in cooperation with M. Gorky Kharkiv State University. and the Joint Institute for Nuclear Research (JINR, Russia) started developing plastic scintillators for the CDF spectrometric complex in the Fermilab Tevatron (USA) [6]. Later, based on these developments, advanced scintillators were created for the ATLAS experiment in LHC [7].

The ISC researchers proposed to use for the CMS experiment detector the lead tungstate scintillation single crystals just developed by them. Detailed measurements of the physical and technical parameters of these crystals confirmed the prospect of the use of these elements in elementary particle detectors. Soon, industrial production of lead tungstate crystals for supplying the elements from them to CERN was launched in Russia (Fig. 1) [8].

The National Science Center Kharkiv Institute of Physics and Technology (NSC KhPhTI) established close creative relations with CERN since the very beginning of its activity [3]. The researchers of this R&D center were directly involved in testing unique radiation-resistant plates of plastic scintillators designed and manufactured by NSC for the detector's front hadron calorimeters exposed to the strongest radiation during the experiments, at the request of CMS. In 2001, the Center started works on the creation of a specialized computing complex for processing and analysis of physical data of the CMS experiment and, in 2005, the CMS-cluster of the NSC KhPhTI was registered in the worldwide LHC-GRID network [9]. Subsequently, the Institute of Scintillation Materials of the NAS of Ukraine, in cooperation with JINR, was developing scintillators with a radiation resistance of 10—100 Mrad for improving the LHC detectors.

Major experiments on the LHC required highly reliable and efficient electrical elements for connecting the respective parts of the detectors. At that time, researchers of Kharkiv Research Institute for Instrument-Making had already elaborated a unique technology for manufacturing microcables and prof. Gennadii Zinoviev, the Head of the Department of Institute for Nuclear Research of the NAS of Ukraine, who already had experience in cooperation with CERN, suggested to CERN to take advantage of the mentioned technology. The development was very interesting for CERN

employees and, thus, a group from Ukraine started creating microcables for the ALICE detector. Subsequently, Kharkiv engineers gained significant authority at CERN as highly qualified specialists in the design and manufacture of microcables for other CERN detectors [10].

In view of Ukraine's increasing contribution to the implementation of experiments on the LHC and to the development of new accelerator technologies, in order to attract it to new CERN activities, a joint declaration was signed in 2011 between the National Center of the Small Academy of Sciences (SAS) of Ukraine and CERN [11]. The Declaration allowed Ukrainian physics, mathematics, and informatics teachers, as well as high school students to participate in CERN's educational activities initiated in 2009. Four scientific schools for teachers and lecturers and five schools for SAS students were organized during the seven years after the signature of declaration. The classes were attended by 105 and 72 participants, respectively. There were organized study tours for school students to major CERN research centers and experiments on the Large Hadron Collider, a series of lectures on the CERN educational program and elementary and high energy physics, etc. [12].

As creative contacts between Ukrainian researchers and CERN expanded, it became clear that under the agreement of 1993 neither enabled to fully utilize the R&D potential of Ukraine in the field of nuclear physics for the implementation of CERN's R&D plans, on the one hand, nor allowed Ukrainian specialists to take advantage of direct involvement in the largest world-class experiments, on the other hand. Ukrainian corporations and institutions did not have access to competitions for the development and manufacture of high-tech and unique products for CERN, and Ukraine could not influence any decisions on R&D development of CERN and its constituent structures, participate in numerous technology transfer programs, etc. as only the CERN members and, partly, the associate members whose status was approved by the CERN Council in June 2010, together with the resolution opening CERN membership to all states, regardless of their geographical location, were authorized to do this.

In order to eliminate these and other obstacles in the development of cooperation with CERN, in October 2013, CERN Director General Rolf Heuer and Vice Prime Minister of Ukraine Kostiantyn Gryshchenko signed the Associate Membership Agreement between Ukraine and the European Organization for Nuclear Research (CERN).

Under the Agreement, given the longstanding cooperation between the Organization and Ukraine, the successful contribution of the latter to the implementation of the CERN scientific program and the existence of a strong, both theoretical and experimental, basis for particle physics in the applicant state, Ukraine was granted with the following rights [13]:

- to be represented at the CERN Council's open and restricted sessions, except for the closed sessions, with rights applicable to the representation of the Associate Member;
- be represented at the sessions of the European Strategy Council as an observer, except for the closed sessions;
- to be represented at the meetings of the Finance Committee;
- Ukraine's Scientific Representative to the CERN Council may attend meetings of the Scientific Policy Committee as an observer.

Ukraine's nationals are eligible to apply for appointment as Staff Members on contracts of limited duration and as Fellows, subject to CERN's Staff Rules and Regulations.

Firms from Ukraine as Associate Member State are entitled to bid for CERN contracts subject to CERN procurement rules and procedures. Ukraine may also appoint a contact person on industrial matters. However, the number of appointments as Staff Members and Fellows, as well as the industrial return and the total value of contracts are limited, with a ceiling that takes into account the Associate Member State's contribution to the CERN budget. The amount payable by Ukraine to the CERN budget is expressed as a per-

Fig. 2. Minister of Education and Science of Ukraine Lilia Hrynevych signs the CERN Associate Membership Agreement

centage of CERN Member State contribution and is defined as a percentage of the Associate Member State's theoretical contribution if it were a Member State, by a formula linked to the Member State GDP and the scale of contributions. In any case, it cannot be less that CHF 1 million annually.

In accordance with the final provisions of the Agreement, it shall enter into force after the completion of all internal procedures for its approval and notification thereof through the diplomatic channels of the Director-General of the Organization. All procedures had to take 24 months. The Verkhovna Rada of Ukraine ratified the Agreement in 2014, but notification was delayed and done as late as at the end of 2016, i.e. 36 instead of 24 months have passed since the signature of Agreement. One of the main reasons for delay of the final approval of the Agreement was the CERN membership fee. According to experts, in order to compensate for these costs and to maximize the benefits of cooperation with CERN, it is necessary to determine the interests of Ukraine in this organization with great responsibility.

To make a comprehensive analysis of the consequences of the Agreement, a special task force consisting of representatives of R&D institutions of the NAS and the MES of Ukraine was established. Together with CERN specialists, it held a series of meetings and discussions and developed a specific roadmap for ensuring the effectiveness of cooperation. On its part, in view of the current situation in Ukraine, despite the annual delay, CERN ratified the relevant agreement documents and, since October 2016, Ukraine has been an associate member of CERN (Fig. 2). A message from CERN CEO Fabiola Gianotti appeared on the CERN website, "*It is a great pleasure to warmly welcome Ukraine into the CERN family. The laboratory has worked closely with Ukrainian colleagues over many years, and we look forward to strengthening this collaboration in the framework of associate membership*". Full Member of the NAS of Ukraine, Prof. Borys Grynyov was appointed as representative of Ukraine in CERN. The task force continues to work, and after the signature of the Agreement, since 2017, the meetings are held four times a year. The Ukrainian delegation to the CERN Council includes Full Member of the NAS of Ukraine, Prof. Borys Grynyov, Full Member of the NAS of Ukraine, Prof. Anatoly Zagorodny as a scientific represen-

tative, Ye.V. Kudryavets and Prof. M.P. Titov as advisers to the CERN Council; S. Shapoval joined the Finance Committee, and T.V. Grynyova is a member of the committee on curricula, teacher and student forums.

According to the Minister of Education and Science of Ukraine Lilia Hrynevych [14], the funds spent by Ukraine as a membership fee to CERN are reimbursed by CERN's compensation for the costs of open access contracts for young researchers from Ukraine to obtain positions at CERN, procurement of products and services of Ukrainian corporations and organizations, which, according to the Agreement, are eligible to the CERN competitions for the development and supply of materials and products for experiments implemented on the LHC (Table 1).

In 2017 and 2018, on a competitive basis, CERN paid for the development and manufacture of materials and products by Ukrainian corporations and organizations for the needs of the existing experiments [15]. The CERN Ukrainian Teacher Program costs CHF 13,000.

As of December 2018, 112 Ukrainian researchers were employed at CERN, including: 1 person in CERN staff, 3 scientists, members of scientific society, 2 doctoral students, 3 students, and 2 project team members, etc.

It is impossible to quantify CERN's investments in Ukraine in the form of technological knowledge that Ukrainian researchers have received during their business trips to CERN, using computing infrastructure, software, information from scientific conferences, schools, seminars, numerous student programs, etc.

So, in April 2017, the Karazin Kharkiv National University, within the Associated International Laboratory for High Energy Physics (LIA IDEATE) established in 2015 by agreement between Taras Shevchenko National University of Kyiv and Karazin Kharkiv National University, the State Fund for Basic Research of Ukraine, the NAS of Ukraine, the French National Center for Scientific Research (CNRS), and the Atomic Energy Commission (CEA Saclay) [16], which was supported by CERN, held *Medical Physics and Visualization* seminar that was attended by more than 70 students, graduate students, and researchers from leading universities and research institutes of Kharkiv, Kyiv, and Sumy, as well as experts from France and the European Center for Nuclear Research (CERN) [17].

Table 1

Missions of Ukrainian Specialists to CERN

Category	2017	2018
CERN Staff	0 months	5 months
Researchers	29 months	49 months
Doctoral students	4 months	27 months
Students with major in engineering	0 months	40 months

In continuation of this series of Franco-CERN-Ukrainian seminars, in March 2019, the Karazin Kharkiv National University hosted the 3rd French-CERN-Ukrainian School of High Energy Physics and Medical Physics. The lectures covered modern radiation detector technologies and imaging systems for biological and medical research. In fact, the school has become a platform for discussing new developments, related devices and treatment methods based on particle therapy and so on. The school attendees familiarized themselves with CERN's experience in conducting research in medical physics [18].

In July 2018, the 12th Trans-European School of High Energy Physics (TESHEP) was held in Poltava [19]. Its main lecture program included Experimental Particle Physics, Standard Model, Cosmology, Statistics, and Instrumentation. TESHEP is a platform aiming at strengthening scientific and pedagogical links between Eastern and Western Europe, and its summer school brings together European students from universities where physics and engineering are a priority.

The most significant event in the field of scientific communication, involvement of Ukrainian researchers and specialists in the most important problems of modern high energy physics, and review of the CERN experiments and capabilities, was *CERN—UKRAINE Collaboration: Current State and Prospects* international conference held in May 2018, on the basis of the Institute of Scin-

Table 2

CERN Educational and Research Programs

Program	Industry	Duration	Conditions
Students with major in engineering; BSc, MSc	Computer technology, engineering, elementary particle physics	4–14 months	18-month Bachelor's program, registered student while staying at CERN
Students with major in management and administration	Translation, HR, finance, paperwork management, law, communications	4–12 months	18-month Bachelor's program
Doctoral students	Applied physics, engineering, computer technology	6–36 months	Doctoral study at a university of CERN Member State
Summer student program	Physics, including elementary particles physics, computer technology	8–13 weeks, in summertime	150 places for the CERN Member States and 150 ones for the CERN non-members
Researchers, specialists	Physics, engineering, computer technology	2–3 years	BSc, MSc, DSc, experience of, at least, 10 years
Engineering specialists	Mechanics, electrics, electronics, etc.	1 year with optional prolongation for 1 year	Diploma in engineering, at most 4-year experience
CERN staff	Physics, engineering, computer technology, administrative staff	Contracts for up to 5 years	From studentship to doctoral degree
Partners, users, specialists, communicants	Experienced specialists, scholars, doctoral students	6–12 months	Leave on the primary place of employment

tillation Materials and Kharkiv Institute of Physics and Technology of the NAS of Ukraine. More than 70 scientists and specialists of research institutions and universities of Ukraine, 9 representatives of CERN and CMS, LHCb, ALICE, SHIP, and CLIC collaborations took part in the conference. The participants presented 45 reports on topical problems of modern high energy physics, prospects for their study, and possible directions of further CERN development. Particular attention was paid to the further development of cooperation between Ukraine and CERN. The conference caused a widespread resonance among experts and it was decided to conduct it on a regular basis with intervals of 2—3 years [20].

CERN pays close attention to various educational and research programs in high energy physics, some of which are listed in Table 2.

In the future, cooperation of Ukraine with CERN is planned to be developed in all directions. Collaboration with CERN allows Ukraine to take advantage of CERN's proclaimed mission [21]:

- to expand the boundaries of knowledge of the universe due to a unique set of technical means;
- to master the most advanced innovative technologies, in particular, information and medical technology;
- to train highly qualified scientists and engineers of the future;
- to promote science and knowledge in society;
- to unite people from different countries and cultures through means of science.

Associate membership gives Ukrainian researchers, specialists, and students an unprecedented opportunity to be involved in the practice of doing research on unique equipment, at the highest level, and to attend the lectures of the most eminent scientists of today. Ukrainian corporations and organizations are eligible to participate in CERN competitions, so they can demonstrate to the world a high level of Ukrainian science, professionalism of scientists and specialists, and aspiration of Ukrainian industry to innovation and high technology.

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УКРАЇНА — CERN: ШЛЯХ ДО СПІВПРАЦІ

Вступ. CERN (ЦЕРН) — це Європейська організація з ядерних досліджень, найбільша в світі лабораторія фізики високих енергій, яка формує творчі відносини між вченими різних країн.

Проблематика. Розвиток міжнародного наукового співробітництва, зокрема створення умов для розширення участі українських учених у проведенні найкрупніших фізичних експериментів з ядерної фізики, отримання нових знань і впливу цих явищ на інноваційні процеси в Україні .

Мета. Аналіз факторів, що сприяють розвитку співпраці між українськими вченими і CERN та окреслення перспектив на майбутнє.

Матеріали й методи. Аналіз наукової діяльності CERN в міжнародному співробітництві та огляд міжнародних наукових проектів CERN в галузі фізики високих енергій.

Результати. Проаналізовано шлях співробітництва з Україною від самого початку створення CERN до підписання угоди про асоційоване членство України в CERN. Наведено приклади позитивного впливу співпраці з CERN на інноваційні процеси в Україні, зокрема в галузі розробки і виробництва нових високотехнологічних матеріалів, без яких важко уявити реалізацію сучасних експериментів з фізики високих енергій. Асоційоване членство дало змогу українським вченим набагато активніше брати участь у вивченні глобальних фізичних явищ всесвіту в найсучаснішій експериментальній лабораторії, а інженерам і технікам освоювати найпередовіші інноваційні технології, зокрема інформаційні та медичні. Окреслено перспективи подальшої співпраці.

Висновки. Співробітництво з CERN дає змогу Україні скористатися у своєму розвитку можливостями проголошеної місії CERN, одним із основних завдань якої є об'єднання людей різних країн і культур через науку. Викладачам, студентам та учням України відкрилися нові можливості роботи з новітніми методами, сучасним обладнанням та інноваційними підходами у справі підготовки висококваліфікованих фахівців з фізики та супутніх галузей науки і техніки.

Ключові слова: дослідження, фізика високих енергій, співробітництво.

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УКРАИНА — CERN: ПУТЬ К СОТРУДНИЧЕСТВУ

Введение. CERN (ЦЕРН) — это Европейская организация по ядерным исследованиям, наибольшая в мире лаборатория физики высоких энергий, которая формирует творческие отношения между учеными разных стран.

Проблематика. Развитие международного научного сотрудничества, в частности создания условий для расширения участия украинских ученых в проведении наиболее крупных физических экспериментов по ядерной физике, получении новых знаний и влияния этих явлений на инновационные процессы в Украине.

Цель. Анализ факторов, которые способствуют развитию сотрудничества между украинскими учеными и CERN, а также определение перспектив на будущее.

Материалы и методы. Анализ научной деятельности CERN в международном сотрудничестве и обзор международных научных проектов CERN в сфере физики высоких энергий.

Результаты. Проанализировано путь сотрудничества с Украиной от самого начала создания CERN до подписания соглашения об ассоциированном членстве Украины в CERN. Приведены примеры позитивного влияния сотрудничества с CERN на инновационные процессы в Украине, в частности в сфере разработки и производства новых высокотехнологичных материалов, без которых тяжело представить реализацию современных экспериментов по физике высоких энергий. Ассоциированное членство дало возможность украинским ученым намного активнее принимать участие в изучении глобальных физических явлений вселенной в самой современной экспериментальной лаборатории, а инженерам и техникам осваивать самые передовые инновационные технологии, в частности информационные и медицинские. Очерчены перспективы дальнейшего сотрудничества.

Выводы. Сотрудничество с CERN дает возможность Украине воспользоваться в своем развитии возможностями провозглашенной миссии CERN, одним из основных заданий которой является объединение людей разных стран и культур через науку. Преподавателям, студентам и ученикам Украины открылись новые возможности работы с новейшими методами, современным оборудованием и инновационными подходами в подготовке высококвалифицированных специалистов по физике и сопутствующих отраслей науки и техники.

Ключевые слова: исследования, физика высоких энергий, сотрудничество.