Russia - CERN cooperation: current status and perspectives

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Abstract. The paper presents the current status and future perspectives of international cooperation of Russia with the European Organization for Nuclear Research (CERN) in the fields of elementary particle, high enegry, and nuclear physics. It briefly describes the history of the Oranization, the development of the USSR and later Russian Federation scientific contacts with CERN and their legal basis, the present state of Russian scientific community involvement in CERN research programmes, as well as the future joint projects. The cooperation in education and training activities is also discussed.

1. Introduction

The European Organization for Nuclear Research (CERN) was created in 1954 by 12 European countries (Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and Yugoslavia).

The idea of organizing an international nuclear research laboratory in Europe was first officially proposed by the French physicist Louis de Broglie in December 1949 at the European Cultural Conference held in Lausanne. Half a year later at the UNESCO General Conference (Florence, June 1950) European scientists Pierre Auger and Edoardo Amaldi with the support of American physicist and Nobel laureate Isidor Rabi tabled a resolution authorizing UNESCO to "assist and encourage the formation of regional research laboratories in order to increase international scientific collaboration . . . ". As a result the European Council for Nuclear Research (in French: *Conseil Européen pour la Recherche Nucléaire*) was born already in 1952, when 11 countries signed an agreement establishing the provisional Council – the acronym CERN appeared. But the official creation date is September 29, 1954, when all 12 member countries ratified the Convention [1] and the Organization officially came into being. The provisional CERN was dissolved but the acronym remained.

Today (2019) the number of CERN Member States has increased to 23: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Spain, Sweden, Switzerland and the United Kingdom. Cyprus and Slovenia are Associate Member States in the pre-stage to Membership. Croatia, India, Lithuania, Pakistan, Turkey and Ukraine are Associate Member States. Japan, the Russian Federation and the USA, as well as the European Union, JINR (Dubna) and UNESCO currently have Observer status.

The Organization is governed by the CERN Council consisting of two official delegates from each Member State. One of them represents the government administration, the other – national

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scientific community. Thus the Council has the opportunity to correlate scientific interests with the financial policy of Member States. The Council has the responsibility for all-important decisions and controls CERN activities in scientific, technical and administrative matters, defines its strategic programmes, sets and follows up the annual goals, and approves its budget. The Council also appoints the Director-General who is the Organization chief executive officer and legal representative. The Council typically meets four times a year under the chairmanship of the President, with the Director-General acting as Secretary.

CERN is located on both sides of the French-Swiss border 10 km from Geneva at the foot of the Jura mountain, the geological and seismic conditions of which are most suitable for the construction of such huge and precise facilities as particle accelerators. Geneva was selected as the site for the Laboratory at the third session of the provisional council in 1952. This choice successfully passed a referendum in the canton of Geneva in June 1953. It was selected from proposals submitted by the Danish, Dutch, French and Swiss governments. But Geneva central location in Europe, Swiss neutrality during the war and the fact that the city already hosted a number of international organizations – all these arguments were in favour of this choice. In addition, the location of the international laboratory on the territory of the two countries is most consistent with the democratic spirit of CERN: openness, cooperation and solidarity in the dissemination of knowledge.

CERN became the first international scientific laboratory in the post-war Europe. At that time the main task for the Organization was set to conduct basic research in the field of high energy and elementary particle physics on the basis of international cooperation, expanding human knowledge on the principles of open research. This meant the publication of all works and the dissemination of the results. All European laboratories, institutes and universities were given the opportunity to collaborate with CERN on the basis of each country contributions to common tasks – all this served the goal to stimulate the development of international cooperation in the post-war Europe and stop the depature of European scientists to the United States, the so-called "brain drain". Gradually, other countries around the world – not only CERN members – got the opportunity to participate in the scientific programs of this international organization. Nowadays, more than 16000 people from around the world work together at CERN to push the limits of human knowledge. CERN staff members numbering around 2500 take part in the design, construction and operation of the research infrastructure. But the real driving force of the research activities, preparation and operation of the experiments as well as the analysis of the scientific data is the vast community of CERN users comprising over 13000 invited scientists and PhD students of 110 nationalities from institutes, universities and research centers in more than 70 countries.

At present time the mission of CERN can be defined as:

- fundamental research in physics by providing a unique range of particle accelerator facilities to researchers and performing the world-class experiments in high energy particle physics and nuclear physics
- technology and innovation transfer to society
- advanced research and development of new information and computing technologies
- training and education
- uniting people from all over the world in their quest for knowledge

The first contacts between CERN scientists and their Soviet colleagues began in late 1950s with the exchange of visits with the physicists from Joint Institute for Nuclear Research (JINR) in Dubna [2]. Later in the 1960s the cooperation developed further when the European physicists arrived in the village of Protvino near Serpukhov to take part in research programmes at the most powerful at that time (76 GeV) particle accelerator at the Institute for High Energy Physics (IHEP). And when the SPS accelerator with a capacity of 400 GeV was built at CERN in 1976 the Russian physicists from many research institutes took part in more than 20 experiments carried out there. Part of this research programme continues today. In general, Russia – CERN cooperation, which has been ongoing for more than 50 years, was especially strengthened in recent years, when the new super-powerful accelerator, the Large Hadron Collider (LHC), was built and commissioned at CERN.

2. Legal basis of Russia – CERN cooperation

The basis of international relations with CERN was laid by the "Agreement concerning Scientific and Technical Co-operation between the European Organization for Nuclear Research and the State Committee of the USSR for the Utilization of Atomic Energy" signed on July 4, 1967 by A.M. Petrosyants (Chairman of the State Committee) and B. Gregory (CERN Director-General). The second step in the development of mutual contacts was the signing of the Protocol of July 10, 1975 to this Agreement on the extension of cooperation on experiments at the SPS accelerator with energy of 400 GeV at CERN. This was followed by the further development of relations with the leading Soviet institutes: Institute for Theoretical and Experimental Physics (ITEP, Moscow), Leningrad Institute of Nuclear Physics (Gatchina), Budker Institute of Nuclear Physics (BINP, Novosibirsk), Moscow Engineering Physics Institute (MEPhI), Moscow State University (MSU), and also with JINR (Protocol of October 25, 1983 to the 1967 Agreement).

The next stage of international cooperation related to the joint research programmes at the Large electron-positron collider (LEP) at CERN, the completion of the design of the LHC, and the construction of the Accelerator-Storage Complex UNK planned at that time at IHEP, was set in the "Agreement between the Government of the USSR and the European Organization of Nuclear Research (CERN) on the further development of scientific and technical cooperation in the field of high-energy physics" signed on May 29, 1991.

After the collapse of the Soviet Union, the participation of Russian scientific organizations in CERN projects was confirmed in the "Co-operation Agreement between the European Organization for Nuclear Research (CERN) and the Government of the Russian Federation concerning the further development of scientific and technical co-operation in high energy physics" (Decree of the Government of the Russian Federation of October 12, 1993 No. 1040), signed on October 30, 1993 by Minister B.G. Saltykov and Director-General C. Rubbia.

According to Art. 6 of this Agreement the Russia-CERN Cooperation Committee was established, co-chaired by the Minister of Education and Science of the Russian Federation and CERN Director-General and consisting of five representatives from Russia and from CERN. The task of the committee is to approve specific scientific, technical and organizational projects and programmes, and review their implementation.

In October 1995 the scientific policy committees of the Russian national programmes on high-energy physics and fundamental nuclear physics at the meeting held in Sarov made an important decision: participation of the Russian Federation in the construction of the LHC and the largest experimental complexes ALICE, ATLAS and CMS was defined as the most important direction of the Russian national programme in high energy and particle physics.

On June 14, 1996 a Protocol to the 1993 Agreement was signed (Decree of the Government of the Russian Federation No. 996-r of June 24, 1996), opening vast possibilities for the Russian science and industry to participate in the LHC project – a priority and global scientific project at the turn of the 20th and 21st centuries. The Protocol provided that the scientific equipment for the construction of both accelerator and experimental facilities – detectors ATLAS, CMS, ALICE and LHCb – with the total cost of about 200 million Swiss francs (in 1996 prices) would be manufactured in Russia. Under the terms of the Protocol, a third of this amount should be allocated by Russia, and one third - by collaborations and CERN. It was assumed that the rest of the equipment cost would be covered by cheaper materials and production, as well as the labor cost in Russia.

The regular LHC project investments began in 1997 by Decree of the Government of the Russian Federation of May 22, 1996 No. 818-r, which provided for the annual allocation of $6 million in ruble equivalent for 10 years from the budget of Ministry of Science.

In 1998 the Russian side signed the Memoranda of Understanding on the construction of ATLAS and CMS detectors, and later – on the construction of ALICE and LHCb detectors, which defined the planned contribution of Russian Federation to the detector production. In parallel with the signing of the Memoranda for each detector, four more Appendices to the 1996 Protocol were prepared and signed, which detailed the distribution of Russian funding, contributions from collaborations, and the planned contribution of Russia to the detector subsystems where the Russian institutions were involved in the construction.

In order to secure the fulfillment of Russia obligations, the Ministry of Science and the Ministry of Atomic Energy developed a joint Decision on financing the work of Russian institutions participating in the construction of the LHC and detectors at CERN, which was signed on January 25, 1999. During the next years the corresponding Decisions on joint financial support of the LHC project were taken on the annual basis.

In accordance with the 1993 Agreement, the Russian Federation allocates foreign currency funds for the maintenance of Russian personnel carrying out work at CERN as part of the obligations on participation in joint research programmes. As an additional justification for allocating the necessary funds, a Protocol was signed in September 2000 to the 1993 Agreement on the status of Russian personnel participating in CERN research projects, providing for payment of staff costs, as well as annual contributions to experiments to cover maintenance and operation costs.

In recent years the financial resources covering the cost of the visits of Russian specialists at CERN to participate in joint research programmes are allocated in accordance with Decree of the Government of the Russian Federation of July 17, 2002 No. 532.

In view of the final stage of construction of the new accelerator and experimental facilities, Russia confirmed the intention to participate in the new phase of the LHC project by adopting the Protocol concerning Participation in the Experimental Programme at the Large Hadron Collider (LHC) (Decree of the Government of the Russian Federation of December 18, 2003 No. 1871-r), signed on December 19, 2003 by First Deputy Minister M. Kirpichnikov and Director-General L. Maiani. This Protocol defined the specific obligations of Russian institutes on the maintenance and operation of experimental facilities, as well as the principles for their financing, which were determined in the Memoranda of Understanding on the maintenance and operation of each of the four experiments and on participation in the project of development of the global distributed computing systems (Grid systems) for LHC (World LHC Computing Grid project – WLCG).

Having the Observer Status with Special Rights, with the right to attend Restricted Sessions of Council for discussions of LHC matters, the Russian Federation announced in 2012 that it began to seek the status of Associate Member State, which implies preferences for the country in the distribution of CERN industrial orders, but also an obligation to pay annual contributions to CERN budget. However, in March 2018, the Ministry of Education and Science of the Russian Federation reported that it was withdrawing the application. Russia, as the ministry said, intends to obtain a special status at CERN, which "will significantly increase the level of cooperation" compared to what Associate membership gives. This new status was enshrined in the agreement signed on April 16, 2019 by First Deputy Minister G. Trubnikov and Director-General F. Gianotti (Decree of the Government of the Russian Federation of April 15, 2019 No. 751-r). There are now two countries at CERN with the special status: Russia and the United States. This special status implies that the corresponding agreement defines a list of experiments and research areas that are of interest to the country (and with which CERN agrees), and that the country will invest resources only for participation in these experiments.

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It should be also emphasized that the main innovation of the new Russia – CERN agreement is its symmetry: it states not only what Russia would like to do at CERN, but also what CERN would like to do in Russia. The previous agreement can be called "one-sided" since it did not say anything about the CERN interest in the experiments being carried out in Russia. Now it is a symmetrical bilateral agreement setting the better conditions for staff, for technology and equipment transfer.

European scientists are going to participate in the experiments at the PIK reactor neutron source (Gatchina), in the construction and experiments at NICA heavy ion collider (JINR), in the development of new technologies for superconducting magnets, in information technologies, and big data analysis systems.

The Russian side confirmed the participation in four major experiments at the Large Hadron Collider: ATLAS, CMS, LHCb and ALICE. In addition, the Russian institutes are going to join the Phase-2 upgrade of the accelerator and experimental facilities, which began in December 2018 and will also participate in non-collider research at CERN – in experiments on the extracted beam, neutrino projects, in the search of rare decays of particles.

The participation of Russian institute in experiments at the collider is also planned after the next upgrade, scheduled for 2024 – 2026, when the LHC will turn into high-luminosity collider – HL-LHC, as well as in the projects which future is not yet clear: in the Future Circular Collider (FCC), and Compact Linear Collider (CLIC).

Following the success of the new Russia – CERN cooperation agreement the Prime Minister of the Russian Federation D.A. Medvedev visited CERN on June 10, 2019 [3]. He has taken a tour to the CERN key scientific instrument – the LHC, situated deep beneath the surface, visited the underground cavern of ATLAS experiment and met with Russian physicists working at CERN in a discussion of the issues of joint scientific research and Russia – CERN international cooperation.

3. Participation of Russian scientific groups in CERN research projects

3.1. The LHC design and construction

The cost of the Large Hadron Collider (not including the cost of the detectors) amounted to approximately 5 billion Swiss francs, while Russia completed work worth more than 150 million Sfr. [4]. For comparison: the US Department of Energy allocated $200 million for the construction of the LHC [5].

At the same time the participation in the LHC project has attracted the foreign investment in the Russian institutions and industry in the amount of about 120 million Sfr. [6]. This made it possible for the institutes to support the scientific and production base, attract students, graduate students and young scientists to advanced scientific research, receive international grants and, as a result, increase their scientific potential.

The most significant examples of the equipment production for the construction of LHC different parts and components that clearly show the emergence and development of unique technologies in Russian research institutes and industrial enterprises are:

- resistive magnets for LHC straight sections (produced by BINP and Novosibirsk enterprise "Sibtekstilmash");
- dipole and quadrupole magnets for SPS-LHC transfer lines (BINP, St. Petersburg JSC "NIIEFA" and Moscow plant "ZVI");
- kicker and septum magnets for injection and beam dump (IHEP);
- switching superconductive buses (BINP);
- energy output system for main superconductive magnets (IHEP and BINP);
- vacuum equipment (BINP);

- electrostatic deflectors (JINR);
- electron cooling for ion beams (BINP).

Russia also participated in the linear injector Linac4 project through three R&D projects, fully financed by the International Science and Technology Center (ISTC).

3.2. Participation in CERN experimental programme

The Russian scientific groups are taking part now in all four experiments at the Large Hadron Collider (ATLAS, CMS, ALICE, LHCb), in the WLCG project for global distributed storage and data analysis as well as in a number of other experiments, being carried out at the CERN accelerator complex.

During the active phase of LHC detector design, construction and initial operation (1997–2013) the Russian contribution to the development of the four detectors in the form of materials and equipment is estimated at the level of 53 million Sfr., and additionally 22 million Sfr. in operating costs (maintenance and operation of the detectors) during this period. The cost of maintaining Russian specialists at CERN participating in the construction and operation of LHC experiments amounted to about 35 million US dollars. As for the USA, for example, their participation in the LHC program is limited to the ATLAS and CMS experiments and the total US contribution to these two detectors amounted to $164 and 167 million, respectively.

ATLAS is one of two main general-purpose detectors at the Large Hadron Collider. The ATLAS collaboration includes about 3000 physicists from 183 institutes in 38 countries, with nine participating Russian institutes: IHEP, BINP, St. Petersburg Nuclear Physics Institute (PNPI), ITEP, MEPhI, Lebedev Physical Institute (LPI, Moscow), Skobeltsyn Institute of Nuclear Physics of Moscow State University (SINP MSU), JINR and Tomsk State University. The Russian contribution of material and equipment to the construction of the ATLAS detector is one of the most significant in the collaboration and it was estimated at the level of more than 15 million Sfr. On the other hand, during the ATLAS detector construction the foreign investments in Russian enterprises, mainly high-tech ones, amounted to over 10 million Sfr. [6].

The CMS detector, like ATLAS, is the general-purpose LHC detector. The CMS collaboration includes over 4000 particle physicists, engineers, computer scientists, technicians and students from around 200 institutes and universities from more than 40 countries. The following Russian institutes are taking part in the experiment: the Institute for Nuclear Research (INR, Troitsk), IHEP, PNPI, ITEP, LPI, SINP MSU, MEPhI, as well as JINR. The organization of RDMS cooperation (Russia and Dubna Member States), combining the efforts of many institutes and scientific schools, allowed physicists from Russia and JINR Member States to take an active part in the construction of individual subsystems and elements of the CMS complex, including the full responsibility for production and installation of the CMS endcap hadron calorimeters and front muon detectors. The total cost of materials and equipment produced in Russia for this experiment is quite close to the one for ATLAS and was estimated at the level of 15.2 million Sfr.

The ALICE experiment is the only experiment at the LHC specifically designed to study collisions of heavy nuclei and heavy ions. The main scientific goal of the experiment is the comprehensive study of the properties and processes of the formation, development and evolution of quark-gluon matter. In total, the ALICE experiment involves about 1900 scientists from more than 140 institutes representing 40 countries including the scientific centers from Russia: ITEP, IHEP, PNPI, National Research Center Kurchatov Institute, INR, MEPhI, BINP, St. Petersburg State University (SPbSU), and JINR. Russia has made a significant intellectual and material contribution to the development and construction of the ALICE experimental facility. One of its largest key detectors – the precision photon spectrometer PHOS – was designed and produced within the framework of the international project ALICE/PHOS with the participation of 14 institutes from 8 countries, including Kurchatov Institute, IHEP, the Russian Federal Nuclear Center VNIIEF (Sarov) and JINR. The PHOS spectrometer is based on lead tungstate crystals which were developed and produced in Russia at Apatity plant "Northern crystals". Russian institutes and JINR have also played important role in the development and construction of dimuon spectrometer (PNPI, JINR, VNIIEF), internal tracker (SPbSU), time-of-flight particle identifier (ITEP), fast trigger detector T0 (INR, MEPhI, Kurchatov Institute, BINP). Taking into account the special Government investment to Apatity plant for the calorimeter crystals production the total contribution of Russian Federation to this experiment was estimated to be more than 17 million Sfr. [4].

The purpose of the LHCb experiment is the most accurate study of B and anti-B mesons properties. The LHCb detector is the specialized instrument designed for this single physics task. Therefore, it is less complex than large multi-purpose detectors like ATLAS and CMS. More than 800 specialists from 79 institutes in 18 countries are participating in the experiment. Russian physicists took an active part in the construction of the subsystems for the LHCb experiment: the mass production technology of electromagnetic calorimeter modules and scintillators was developed in ITEP and IHEP, 600 out of the total number of 1380 fast muon detectors were assembled in PNPI, the production of electromagnetic and hadron calorimeters modules was entirely done in Russia. About 150 physicists, engineers and students from 11 Russian institutes are now involved in the experiment operation, software development and physics data analysis.

Besides the experimental physics programme at the LHC, Russia participates in the global computing project WLCG as a federation of several centres at the Tier-2 level (RuTier-2), supporting data storage and computational requirements of all four LHC experiments.

The Russian institutes are also contributing to the experimental programme being carried out at CERN Super Proton Synchrotron (large and medium-scale experiments AWAKE, COMPASS, NA61, NA62, NA64, SHiP) and to other smaller experiments at CERN accelerators as well as to a number of R&D projects.

4. Collider and experimental facilities upgrade programme

The next CERN project is High Luminosity LHC (HL-LHC), which is aimed at ten-fold increase in the luminosity of proton-proton collisions at energy of 14 TeV, will be carried out by the successive commissioning of several new elements of the CERN accelerator chain and a number of technical improvements being implemented in 2013-2026.

The HL-LHC project includes the replacement of several accelerators in the LHC proton injector circuit, the upgrade of beam intersection regions, and the improvement of detectors in all four experiments. The physical programme of the upgraded LHC operating at luminosity of 10^{35} cm^{-2} sec^{-1} includes new physics tasks that cannot be accomplished with the present collider design.

These tasks can be carried out using relatively small additional resources compared to the initial cost of the entire accelerator complex, which will significantly extend and expand the collider physics programme, providing smooth transition to future high-energy physics projects.

For the successful implementation of this programme the experimental setups should provide the same particle registration properties as with the standard LHC luminosity of 10^{34} cm^{-2} sec^{-1} and this will undoubtedly require their modernization.

In order to be able to fully exploit the planned HL-LHC upgrade, all four LHC collaborations have proposed the upgrade programmes of the detectors consisting of modifications and replacement of some existing subsystems as well as new additions to the detectors. These upgrade programmes are divided into two phases: Phase-I for the items to be installed in or before the second Long Shutdown (LS2) in 2019-2020, and Phase-II for items to be installed in the third Long Shutdown (LS3) in 2024-2026.

Russian research teams are now successfully participating in both phases of detector and collider upgrade programmes. Their total contribution in the form of new materials and equipment during the whole upgrade campaign till the end of LS3 can be estimated at the level of 5 – 10 million Sfr. per each experiment.

5. CERN future projects

CERN community has already started the planning for the future post-LHC era, undertaking the design studies for accelerator projects of the second half of this century with the emphasis on proton-proton and electron-positron high-energy frontier machines [7]. These design studies are to be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide. The Russian scientists have also started participating in these studies.

The two projects being developed now at CERN are: the compact linear electron-positron collider (CLIC) [8] and the Future Circular Collider (FCC) in two operational modes, as an e^+e^- collider [9] and a pp collider [10].

The CLIC linear collider would start as a Higgs, WW and $t\bar{t}$ factory at collision energy 380 GeV, while the tunnel could be extended with time to achieve the energy of 1.5 TeV in the second stage and to 3 TeV in the final stage. The whole programme would last 34 years from the start of the construction.

The FCC design is such that it could start as an e^+e^- collider (FCC-ee) evolving in time from a Z, H, WW and $t\bar{t}$ factory by increasing the collision energy from about 90 GeV to 365 GeV. In the second stage, the FCC would be turned into 100 TeV pp machine (FCC-hh) with high-field magnets of up to 16 T, also suitable for heavy-ion collisions. With the addition of an energy recovery electron linac (ERL) of 60 GeV, also electron-proton interactions could be explored providing additional input to achieve the ultimate precision of the FCC-hh. This integrated FCC programme would last 70 years from the start of the project implementation.

As part of the FCC project studies, also a high-energy version of the LHC (HE-LHC) with FCC-hh magnets and conversely a low-energy FCC-hh with the LHC-type magnets were considered [11]. While these options would push the energy frontier, they were deemed less attractive than the FCC integrated programme.

The careful evaluation of these projects did not yet find any show-stoppers on the technical side, however there are still challenges ahead with time scales for addressing them quite uncertain, more so in the case of FCC-hh than for CLIC. In the global context, CLIC and FCC-ee are competing with the International Linear Collider (ILC) [12] project proposed to be built in Japan, and with the project of circular electron-positron collider CEPC in China [13]. In the latter case, the CEPC could be turned at a later stage into a pp collider similarly to the FCC project. As Higgs factories, all the four contenders have a similar reach. There are no major technical obstacles for their realisation, however more effort is required before construction of any of them could start.

6. Educational activities of CERN, training programs for Russian teachers and students

In addition to its main function as an international laboratory for fundamental science, CERN still serves as a major research and educational center. In the LHC experiments, e.g. ATLAS and CMS, up to 30% of all employees are senior students and PhD students. The international scientific community understands that one of the most important tasks is the training of young personnel, whose activities in the future will be associated with experimental research both in the field of high-energy physics and beyond. To ensure the successful operation of the existing facilities and their modernization over the next 15–20 years, to obtain new physical results, it is necessary to create new mechanisms for training and retaining young scientific personnel (students, graduate students, operational staff, etc.) to work at the facilities, control experiment and analysis of physical data.

Therefore, CERN has developed a special program of students Summer School, which provides senior students studying in the field of physics, computing and engineering disciplines with a unique opportunity to participate in the daily work of scientific groups involved in CERN experiments. In addition to the outstanding first-class scientific experience, students can also gain work practice in an interdisciplinary international environment, which will naturally contribute to their professional career. This opportunity provides a unique chance to establish scientific contacts with other students and scientists from all over Europe. Additionally to daily work in scientific groups, students also attend a series of lectures specially prepared for them. Prominent scientists from around the world give lectures to students on a wide range of issues of modern theoretical and experimental elementary particle physics and computer engineering and programming. The total volume of the lecture course is 100 - 110 acad. hours. This training course also includes visits to the CERN accelerator and experimental facilities, discussion seminars, meetings, and poster presentations. The entire program of students Summer School takes from 8 to 13 weeks. The scholarship for this time and flight to Geneva and back is fully paid by CERN. Every year, more than 200 students, mainly from European countries, participate in the Summer School. This number also includes a few students from non-Member States, for example, the quota from Russia over the recent years has been holding at 10 people.

In addition to Summer School program for senior students, CERN has developed the advanced training courses for high and secondary school physics teachers. This program is also aimed mainly at teachers from CERN Member States, however, over the past years, CERN together with JINR, has been organizing a special weekly school for Russian physics teachers. Several such schools have already taken place, with participation of 30-40 teachers. Additionally to this educational program for Russia, CERN also holds regular video conferences and remote master classes for Russian students, conducting them mainly with those schools in Russia from which physics teachers have already come to CERN.

7. Conclusions

The active participation in international high energy physics collaborations allows Russia to receive benefits for domestic accelerator programmes in three areas: the possibility of developing and obtaining important technical and innovative resources, the technological labor sharing, and the exchange of its results among partner countries in collaboration, and involvement of young scientists and specialists in this process.

The international partnership ensures the distribution of these activities across different regions, thereby eliminating duplication in the concentration of efforts, and also initiates the motivation of each country or participant to develop its own set of resources in order to fulfill its obligations to the collaboration.

It is obvious that the results of global international cooperation in the field of nuclear physics and accelerator technologies, particle physics and high energy physics will be actively exploited and used in Russia for the development of scientific research and high technologies in many priority areas due to their scale and universality.

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