OPEN INFORMATION AND EDUCATIONAL ENVIRONMENT FOR SUPPORTING FUNDAMENTAL AND APPLIED MULTIDISCIPLINARY RESEARCH AT JINR

EDU Open Education at JINR

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JINR OPEN INFORMATION AND EDUCATIONAL ENVIRONMENT

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PROJECT LEADER: YU.A. PANEBRATSEV

DATE OF SUBMISSION OF PROPOSAL OF PROJECT TO SOD _________

DATE OF THE LABORATORY STC _________ DOCUMENT NUMBER _________

STARTING DATE OF PROJECT ________________

Form No. 25

PROJECT ENDORSEMENT LIST

OPEN INFORMATION AND EDUCATIONAL ENVIRONMENT FOR SUPPORTING FUNDAMENTAL AND APPLIED MULTIDISCIPLINARY RESEARCH AT JINR

JINROPEN INFORMATION AND EDUCATIONAL ENVIRONMENT

CODE OF THEME: 06-0-1139-2019/2023

NAME OF PROJECT LEADER: YU.A. PANEBRATTSEV

APPROVED BY JINR DIRECTOR	SIGNATURE	DATE
ENDORSED BY		
JINR VICE-DIRECTOR	SIGNATURE	DATE
CHIEF SCIENTIFIC SECRETARY	SIGNATURE	DATE
CHIEF ENGINEER	SIGNATURE	DATE
HEAD OF SCIENCE ORGANIZATION DEPARTMENT	SIGNATURE	DATE
LABORATORY DIRECTOR	SIGNATURE	DATE
PROJECT LEADER	SIGNATURE	DATE
ENDORSED		
RESPECTIVE PAC	SIGNATURE	DATE

Form No. 26

Schedule proposal and resources required for the implementation of the Project

OPEN INFORMATION AND EDUCATIONAL ENVIRONMENT FOR SUPPORTING FUNDAMENTAL AND APPLIED MULTIDISCIPLINARY RESEARCH AT JINR

(Project title)

<table>
<tr><th colspan="3" rowspan="2">Expenditures, resources, financing sources</th><th rowspan="2">Costs (k$)
Resource requirements</th><th colspan="3">Proposals of the Laboratory on the distribution of finances and resources</th></tr>
<tr><th>1st year</th><th>2nd year</th><th>3rd year</th></tr>
<tr><td colspan="2" rowspan="3">Expenditures</td><td>Main units of equipment, work towards its upgrade, adjustment etc.</td><td>120</td><td>40</td><td>40</td><td>40</td></tr>
<tr><td>Construction/Renovation of premises</td><td>–</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td>Materials</td><td>15</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td>Required resources</td><td>Standard hour</td><td>Resources of
– Laboratory design bureau;
– JINR Experimental Workshop;
– Laboratory experimental facilities division;
– accelerator;
– reactor;
– computer.
Operating costs.</td><td>–</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td rowspan="2">Financing sources</td><td>Budgetary resources</td><td>Budget expenditures including foreign-currency resources.</td><td>1 185,9</td><td>395,3</td><td>395,3</td><td>395,3</td></tr>
<tr><td>External resources</td><td>Contributions by collaborators.
Grants.
Contributions by sponsors.
Contracts.
Other financial resources, etc.</td><td></td><td></td><td></td><td></td></tr>
</table>

PROJECT LEADER

SIGNATURE

Form No. 29

Estimated expenditures for the Project

Open information and educational environment for supporting fundamental and applied multidisciplinary research at JINR

(full title of Project)

	Expenditure items	Full cost	1st year	2nd year	3rd year…
	Direct expenses for the Project				
1.	Accelerator, reactor	hours	—	—	—
2.	Computers	hours	—	—	—
3.	Computer connection	k$	—	—	—
4.	Design bureau	hours	—	—	—
5.	Experimental Workshop	hours			
6.	Materials	k$	5	5	5
7.	Equipment	k$	45	45	45
8.	Construction/repair ofpremises	k$	—	—	—
9.	Payments for agreement-based research	k$	140	140	140
10.	Travel allowance, including:	k$	10	10	10
	a) non-rouble zone countries				
	b) rouble zone countries				
	c) protocol-based				
	Total direct expenses	**600**	**200**	**200**	**200**

PROJECT LEADER

LABORATORY DIRECTOR

LABORATORY CHIEF ENGINEER-ECONOMIST

Abstract

Project goals

- Use of modern educational technologies for various training of students and specialists for work at JINR. Attracting of talented youth from the participating countries to work at JINR.
- Integration of the results in the field of fundamental and applied research obtained at JINR into the educational process in the JINR Member States and Associate Members.
- Collaboration with leading world scientific centers (CERN, BNL) in the field of creating educational resources for physics teachers and high school students.
- Promotion of fundamental and applied multidisciplinary research conducted at JINR and the JINR brand among a wide audience. Development of courses prepared by the leading JINR specialists for international open education platforms.
- Creation of educational and exhibition content on JINR topics at the level of leading research centers.

The main expected results of the project

- Development of the JINR Educational Portal. Creation of online courses for students and post-graduates of the JINR Member States and Associate Members, as well as countries collaborating with JINR on topical problems of modern physics (research on nuclear matter and particle physics at colliders, search for superheavy and exotic nuclei, neutrino physics, condensed matter research matter and nanostructures) and multidisciplinary applied research with heavy ions, neutrons and synchrotron radiation in the field of materials science, life sciences and radiation biology.
- In collaboration with the JINR basic departments and universities of the JINR Member States and Associate Members, the inclusion of online courses, created by the specialists of the JINR Member States and Associate Members, into the curricula of these universities and publishing of courses on leading open education platforms.
- Creation of a complex of virtual, remote and hands-on practicums and research based on real experimental data. Creation of an open Internet environment for experiment modeling to study nuclear physics.
- Creation of multimedia courses, organizing of workshops, lectures and practicums with the possibility of remote access to the platform with laboratory works on nuclear physics for teachers and high school students.
- Creation of modern multimedia interactive expositions using virtual (VR) and augmented (AR) reality technologies devoted to JINR current scientific projects and scientific achievements. Preparation of a stationary exhibition in Dubna for the 65th anniversary of JINR and mobile exhibitions in countries collaborating with JINR.

Over the past 15 years, project team has participated in the creation of educational, popular and science outreach projects at the national and international levels.

1. Introduction

The Joint Institute for Nuclear Research is an international scientific center in which unique basic facilities have been created and are currently being developed, and research is being carried out in topical scientific areas: studies of condensed matter with a pulsed fast neutron reactor, search for new superheavy elements, neutrino physics research, research of relativistic nuclear collisions and the creation of the NICA superconducting collider.

An extremely wide range of scientific and engineering, technological and technical tasks facing JINR specialists requires an integrated approach to training personnel for work in JINR laboratories and departments. First of all, this is the creation of training courses and new educational programs on the topic of priority areas of JINR research. Then – the inclusion in the educational programs of universities and postgraduate education of scientific and applied results obtained at JINR laboratories. Such scientific results and technological solutions should also be accompanied by popular science and educational projects, including materials for the school audience. This will help in the future to overcome a serious social problem – a decreasing young people's interest in scientific research and engineering.

The rapid development of information and communication technologies and the widespread use of the Internet has led to a qualitative change in the pedagogical technologies used throughout the world. Today, blended learning is becoming a popular form of training, when along with the full-time educational process, computer-based teaching tools are widely used: online courses, interactive practicums and laboratory works, computer modeling tools and simulators. In this regard, the technological component of the JINR educational project should be consistent with current trends in this field.

During the project realization, an open information and educational environment (OIEE) will be developed to support fundamental and applied multidisciplinary research at JINR, including the following components:

- development of the JINR educational portal with online courses and new educational programs on the topic of JINR projects;
- information and educational support for JINR projects;
- multimedia exhibitions on the topic of JINR projects;
- an educational resource for studying nuclear physics and experimental techniques with virtual, remote and hands-on practicums.

The developed online courses will allow to form educational programs for joint training of masters with the participation of universities of the JINR Member States and Associated Members. Courses will be developed in the MOOC format (Massive Open Online Courses) and hosted on the appropriate open source platform.

When developing course materials and educational sections of the sites, modern technologies of dynamic interactive 2D and 3D web graphics will be used. The use of international standards that define requirements for the organization of educational material will ensure the compatibility of individual components of the OIEE and create opportunities for their multiple use. During the development of test and control materials, the LTI (Learning Tools Interoperability) specification will be used. It will contain recommendations for the structure and rules for developing educational applications for their integration with various learning management systems (LMS).

2. State of research on the stated scientific problem

Today, an important place is given to the task of integrating science, education and innovative activity as one of the decisive factors in the development of a knowledge-based economy and society. Under existing conditions, solving the problem of integrating education and science means establishing effective and sustainable interaction between universities and research centers and institutes [1]. Increasing the role of solving problematic situations in the learning process, transferring them to the research field will provide students with direct access to the world of science, and will expand the possibilities of their research activities [2].

To solve these problems, it is necessary to combine the efforts of various universities and research centers to create new training courses and research practicums. Here, of course, existing methods of modern education will be used. And very important here is the task of creating an open educational information environment using distance and online learning technologies to train specialists for work in modern scientific experiments.

The first three online courses on “Introduction to Artificial Intelligence” from Stanford University were published in 2011 and attracted about 160,000 students from 190 countries. A year later, in 2012, two Stanford University professors, Andrew Ng and Daphne Koller, founded Coursera company, which began working with various universities in order to create massive open online courses (MOOCs). In the same year, the Massachusetts Institute of Technology together with Harvard University introduced the edX platform. And in 2013 the open-source platform – Open edX – was published. It became available for use by other educational institutions and private individuals [3].

In our country the National Open Education Platform (openedu.ru) was created and is being developed. It is an educational platform that offers online courses in basic disciplines studied at Russian universities. The platform was created by the Association “National Platform for Open Education”, established by leading Russian universities [4].

Currently open online courses have shown their effectiveness for additional education in various fields. According to the Class Central resource for 2018, the total number of MOOC students worldwide reached 100 million, and by the end of the year more than 900 universities around the world announced the launch or opening of 11.4 thousand of MOOCs [5, 6, 7]. However, among ready online courses, there are relatively few specialized courses developed by scientists working in modern scientific experiments. Such online courses can contribute, on the one hand, to attract the attention of students to the topics of modern experiments, and, on the other hand, reduce the time for training personnel for these experiments.

There isseveral problems that cannot be solved by the modern MOOC model:

- an analysis of the needs of scientific centers for the formation of a list of positions and corresponding competencies for young specialists;
- formation of a list of courses and the content of educational materials, considering the agreed position of teachers and employers – scientists and engineers;
- formation of training materials considering the knowledge of experts working directly in this subject area and not conducting regular teaching activities.
- development of training courses based on the results of individual research groups and experiments;
- rapid change of training materials and practical tasks, considering rapidly changing technologies;

- search for topics for scientific and engineering research and potential scientific leaders already at the stage of passing the corresponding online courses;
- formation of the employer's opinion on the results of the student’s online training for the subsequent continuation of his career in a scientific center (in an experiment).

The largest international scientific centers – the European Organization for Nuclear Research (CERN) and Brookhaven National Laboratory (BNL) pay great attention to the development and implementation of educational programs for teachers, university and school students. In addition to full-time classes conducted as a part of student practices, physics teacher schools, open door days, etc., CERN and BNL regularly post interactive multimedia educational resources for university and school students [8, 9] in the form of scientific and popular science articles, video lectures and interactive educational games even for children [10, 11, 12].

Another area of application of modern information technologies for the training of engineering and scientific personnel is the use of virtual instrument technology, a combination of mathematical simulation and hardware and software technical means. The main feature of virtual devices is the most complete simulation of physical devices (front panels, scales, arrows and other elements of devices) and their controls (buttons, toggle switches, etc.), as well as the reaction of devices to user activity.

The advantage of virtual instrument technology is the opportunity based on the potential of modern computer technology and its integrability with measuring instruments, to create various measuring instruments, measuring systems and software and hardware systems, easily adapt them to changing requirements, minimize economic and time costs for design and development.

Systems based on virtual instrument technology are used both for the automation of technological processes and for the construction of interactive educational environments and individual virtual laboratories. The set of virtual instruments is called the “virtual laboratory”.

From the point of view of engineering activities and the training of engineers, virtual practicums can be considered as a method of modeling the activities of a future specialist, in which his research competence is formed.

The advantages of using virtual laboratories in the educational process include the following:

- additional opportunities to increase the role of student self-development and the individualization of his work;
- availability of a remote virtual laboratory at any time for all university structural units, as well as individually for students with a personal computer and Internet access;
- automation of tracing student practicum results by a teacher.
- opportunity to work with devices and phenomena not available in an ordinary laboratory, including the reason of strict radiation safety requirements;
- exclusion of possibility of breakage or malfunction of measuring instruments, that ensures safe work with devices.

Due to these advantages, the technology of virtual devices is widely used in the field of traditional and distance engineering education.

Virtual devices, as simulators, are more often used in distance learning (web-based solutions), since organizing access to real experimental setups and taking measurements on them is a rather expensive and complicated task. In traditional education, virtual devices are also used based on the integration of hardware and software with a computer.

Unfortunately, the number of currently existing virtual laboratories used in the educational process in Russia is quite small. This is due, first, to the high cost of their development, which leads to the following consequences:

- Virtual laboratories developed by professional programmers, designers and specialists in the simulated field are very expensive, which prevents their wide distribution. On the other hand, small distribution opportunities lead to small incentives for their production.
- The creation of virtual laboratories by non-professionals can lead to satisfactory results only when modeling a narrow class of phenomena. Their distribution is associated with low cost and the practical lack of alternatives.

Of course, virtual labs have some drawbacks. The main one is the lack of direct contact with the object of study, instruments and equipment. Experience with real instruments is necessary, therefore, a combination of using real and virtual laboratories in the educational process, taking into account their inherent advantages and disadvantages, is a reasonable solution. [13, 14, 15]. That is why it is proposed in this project an integrated solution – a virtual laboratory, remote and hands-on practicums.

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3. Description of the proposed research

Solving the problem of integration of education and science means establishing effective and sustainable interaction of universities with research centers and institutes. The main mission of the JINR laboratories is the generation of new knowledge. For their successful development, laboratories need to attract talented youth and highly qualified specialists to work at JINR. At the same time, highly qualified specialists work at JINR. And they could transfer their knowledge in the form of online courses, lectures, practices, joint research work for students from various universities of Russia, theJINR Member States and Associated Members.

3.1. Online courses for the JINR Educational Portal (edu.jinr.ru)

Modern scientific centers today face a number of educational tasks, which can be greatly solved by online courses and other computer educational tools developed jointly by specialists working in priority research areas and university professors. These tasks include:

- increasing the attractiveness of scientific and engineering careers for university students and graduates;
- attracting young scientists and specialists to participate in existing research projects;
- reduction of the starting period for a student or young specialist to become involved in a research project;
- inclusion of courses as elements of distance education in the universities with limited number of specialists of the corresponding profile;
- the possibility of including materials related to modern achievements in the field of science and technology in traditional training courses;
- advanced training for school and university teachers;
- popularization of modern scientific research, scientific and technological achievements.

To solve these problems, the Open Educational Portal has been created and is being developed at the Joint Institute for Nuclear Research in Dubna. It targets university and school students of the JINR Member States and Associated Members, young specialists and science teachers. The portal hosts courses in the MOOC format on priority JINR activities. The first courses on the topics of the NICA project, on heavy ions and the synthesis of new elements, fundamental and applied research of nanostructures and condensed matter using neutrons have already been created and published. It is planned to create courses on the use of neutrons in ecology and environmental sciences, nuclear planetology, and radiobiology.

At the JINR University Centre (UC) special face-to-face courses for graduate students are currently offered. With some degree of conditionality these courses can be divided into the following categories:

- Experimental physics of elementary particles
- Experimental nuclear physics
- Theoretical physics
- Nuclear methods in applied research
- Accelerator technology
- Modern information technology in science

It is these areas that are supposed to become the foundation for the structure of new online courses at the JINR Educational Portal. That will significantly expand the audience of students. According to the new educational standards, universities can officially offer a certain number of distance courses. That is why online courses of the JINR Educational Portal can be demanded by the corresponding departments of Russian universities as elements of educational programs.

An even more interesting task is to create a series of logically interconnected online courses that will represent one or another specialization.

JINR specialists, representatives of universities of the JINR Member States and Associate Members, and representatives of the basic departments of the JINR University Centre expressed their desire to create educational content for online courses.

To organize the learning process, the MOODLE learning management system was deployed on the portal.This system is the most popular LMS and is used at most universities. It allows to solve a wide range of tasks related to the organization and support of the educational process.

3.2. Development of the project “Virtual Laboratory for the Study of Nuclear Physics”

The team proposing this project had previously created the software and hardware complex "Virtual Laboratory for Nuclear Fission". Together with the JINR staff, specialists from Bulgaria, Serbia, South Africa, Mongolia and the Russian Federation took part in this work. Virtual practicums created in the framework of the project are used in universities in various countries.

This project proposes the further development of this activity in several new directions.

I. ***Virtual laboratory of gamma spectrometry***consistsof the following virtual practicums:

- single-crystal scintillation gamma spectrometer;
- semiconductor Ge (Li) gamma spectrometer;
- semiconductor X-ray spectrometer. Mosley's Law;
- use of low-background gamma spectroscopy laboratory data for quantitative and qualitative analysis of samples;
- gamma spectroscopy using silicon photomultipliers;
- research projects.

The virtual practicums will include research laboratory works proposed by JINR laboratories (FLNR and LHEP), Sofia University (Bulgaria) and the University of Novi Sad (Serbia).

II. ***Virtual laboratory for detectors and signal processing***consists of educational materials about the structure and the physical principles of operation of detectors for various nuclear physics experiments, as well as virtual practicums on the stages of processing of signals obtained in physical experiments using digitizers. The section “Training” includes:

- Interaction of radiation with matter
- Sources of radiation
- Radiation detectors

- Fundamentals of nuclear electronics. Data acquisition systems
- Modern methods of reading signals from detectors using digitizers
- Signal processing methods. Fundamentals of working with signals from modern digitizers
- Analysis of signals and spectra from detectors using ROOT environment

The section “Practicum” will include a set of interactive experimental research works on radiation registration and design of detection systems using scintillation, semiconductor detectors, detectors based on microchannel plates. This section will include the following components:

- libraries with arrays of real experimental data from scintillation detectors of various types, semiconductor detectors and time-of-flight detectors based on microchannel plates obtained using digitizers;
- a set of virtual practical tasks and laboratory works based on using real experimental data;
- guidelines for the implementation of practical tasks and laboratory works based on using real experimental data.

III. **A set of virtual practicums** includes training courses on experimental data processing methods and practicums on the analysis of experimental data in ROOT environment.

IV. **Introductory distance course "Introduction to Experimental Nuclear Physics"** with interactive computer models of detectors and physical processes occurring in them, animations and computer models of various experiments and technical devices.

3.3. Hands-on practicum

As part of the professional training in experimental physics, a virtual practicum can solve a limited range of problems. A hands-on practicum with real physical equipment should be the main training tool. It should be aimed to develop the skills of planning, organizing and conducting an experiment, as well as solving a wide range of problems that arise when working with any physical equipment.

Over the past few years, the authors of the project participated in organizing and conducting several international practices for university students, in which students studied the operation principles of nuclear physical equipment, participated in nuclear physical measurements, and made individual research.

The project proposes the development of hands-on practicums that include the following experimental studies:

- work with an oscilloscope to measure signals from the generator;
- assembling of a scintillation telescope for registration of cosmic radiation;
- measurement of energy resolution of scintillation and semiconductor detectors;
- measurement of energy of charged particles and nuclear fragments using semiconductor detectors;
- measuring the time of flight of particles using time-stamp detectors based on microchannel plates;
- study of properties of X-ray radiation, verification of Mosley's law;
- measurement of gamma-ray spectra and their analysis;
- work with detectors based on silicon photomultipliers;

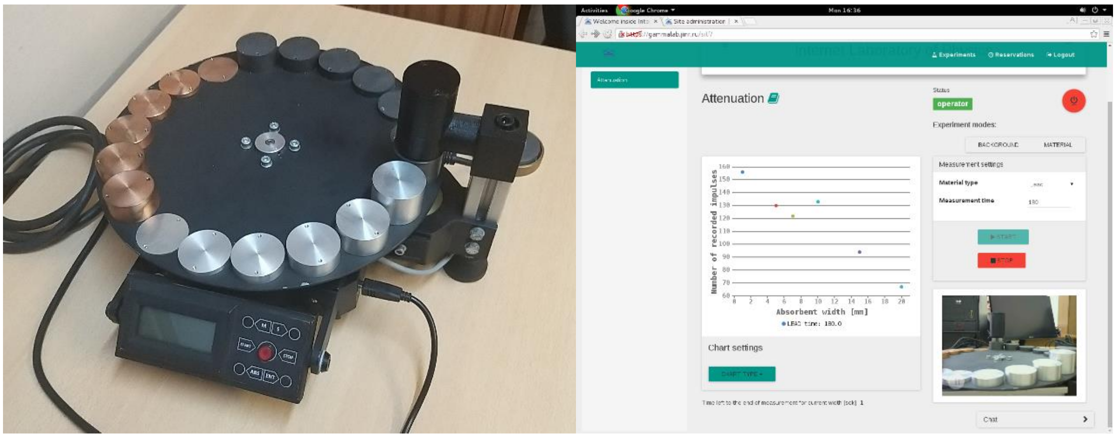
- impedance measurement of the read line of the detector based on MRPC (Multigap resistive plate chamber);
- work at the stands for testing detectors with space muons;
- creation of microstrip detectors;
- study of vacuum systems;
- study of the gas supply systems of detectors.

Within the framework of this project, it is proposed to significantlyextend the range of tasks to be solved, on the one hand, and, on the other hand, to extend the experimental base for practicums, supplementing it with new experimental equipment. It will also require the development of new teaching materials, taking into account the initial knowledge level of university and school students.

3.4. Platform for remote practicums in nuclear physics

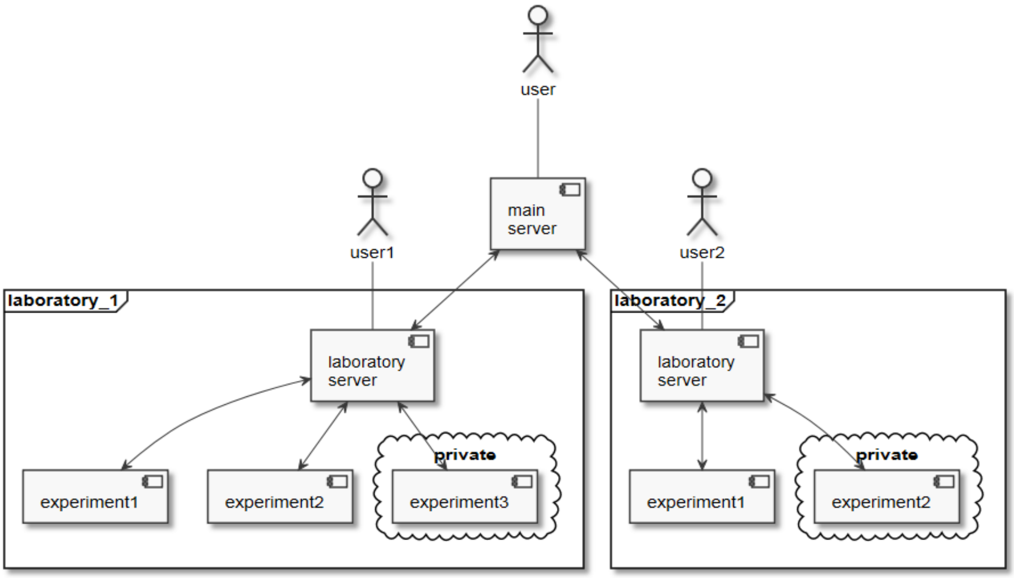
Together with hands-on and virtual practicums, the development and use of experimental equipment and related software for remote-controlled physical experiments are of great importance in the training of future experimental physicists and engineers. Such the practicums also have the opportunity of saving experimental data for further processing and analysis.

The development of remote experiments is a task that requires large material and intellectual costs, so individual universities often do not have the possibility to develop their own experimental complexes, or they realize this idea in a very limited amount. Therefore, the task of combining the efforts of various universities in this very promising direction and the development of a “universal” platform for including various remote experiments seems relevant.



An example of a remote experiment to study the absorption of gamma radiation by various materials

In the framework of the project, it is proposed to unite the efforts with Warsaw Polytechnic University to develop a platform for remote practicums on nuclear physics. This platform will primarily support the opportunity to connect various types of equipment to this platform using a single data exchange protocol.



Generalized architecture of a distributed platform for integration and use of remote experiments from various developers

The platform will include appropriate web services that allow students from universities of the JINR Member States and Associated Members to reserve the time of the experiment, remotely launch experimental equipment, receive experimental data for further processing and analysis, and exchange the results of experiments between users of this platform. This part of the project can also become the basis for an engineering and technical practicum, for example, for the International Engineering School of Dubna State University.

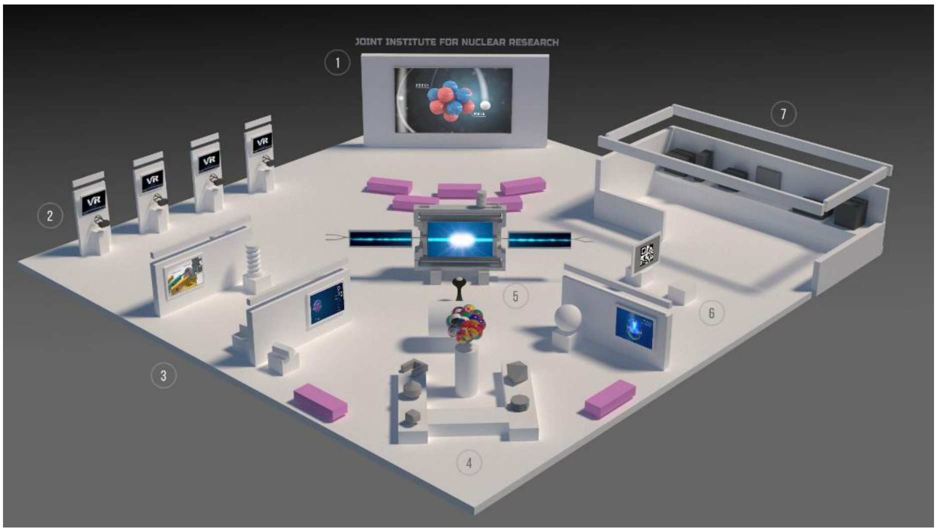
Developing an environment for remote experiments can become the basis for teaching students not only how to set up an experiment according to the suggested scenario, but also for giving them the skills associated with setting up their own experiments using the special sets of experimental equipment and corresponding electronics (CAEN, Nuclear National Instruments, etc.).

3.5. JINR Expositions

JINR is the largest multidisciplinary research center, which implements the most advanced research projects. All leading world scientific centers have a wide range of events for society: exhibitions, open days, science museums, programs and events for teachers, university and school students based on these centers. An example is the stationary expositions of CERN in the Microcosmos Museum and the traveling exhibitions of CERN in various countries of the world (for example, an exhibition in Bahrain:http://shaikhebrahimcenter.org/en/event/cern-in-bahrain/).

Within the framework of this project, it is proposed to create stationary and traveling exhibitions illustrating science activities of JINR as the largest international scientific center at the level of exhibitions of the world's leading scientific centers.

In order to attract the attention and interest of modern visitors to scientific and educational events, it is necessary to use not only modern multimedia information technologies, but also real interactive models and samples. Using a combination of real exhibits and multimedia presentations based on virtual (VR) and augmented (AR) reality, one can clearly explain some complex physical processes and phenomena, the principles of operation of various elements of nuclear physics facilities and demonstrate the most advanced technological solutions. In addition, it is proposed to include lectures from leading JINR scientists and specialists, hands-on practicum with real experimental equipment and a virtual practicum on experimental nuclear physics.



Preliminary 3D-model of the JINR exhibition

A detailed description of the proposed JINR exhibition is given in Appendix 2.

On the stage of the exhibition design it is supposed to create several workstations for virtual and remote practicums and supply these workstations with equipment for hands-on practicum. This equipment may include pulse generators, oscilloscopes, a scintillation telescope for detecting cosmic radiation, semiconductor detectors and time-of-flight detectors based on microchannel plates, detectors based on silicon photomultipliers, digitizers and computers for signal analysis.

Some elements of the proposed exhibition are supposed to be located at the JINR Museum of Science and Technology, the Slovak Technical Museum, and the Educational center named after academician A.N. Sissakian, located at Dubna State University. In addition, it is proposed to involve students and teachers in the development of some expositions as part of the undergraduate and master's works, as well as in the framework of training at the International Engineering School of Dubna State University.

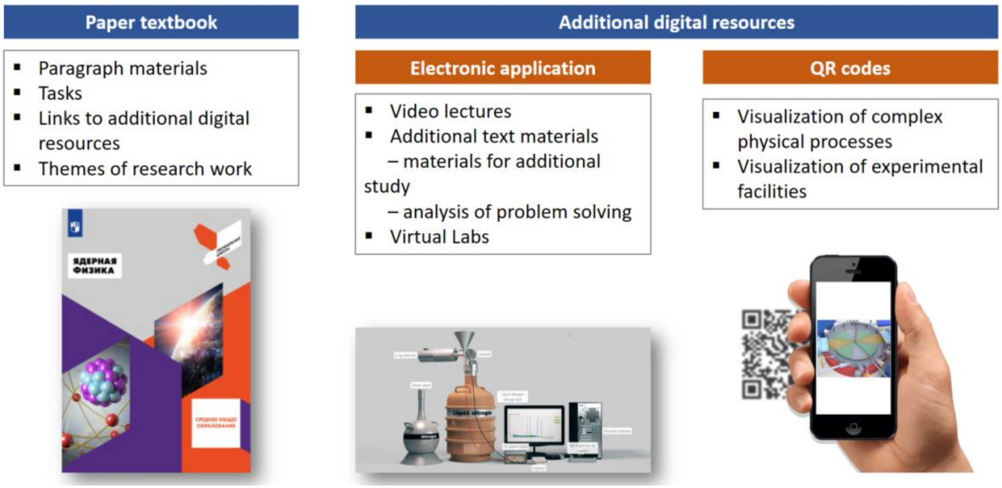
3.6. Development of multimedia educational resources for physics teachers and high school students

The implementation of international modern research projects makes an invaluable contribution to the solution of such a fundamentally important problem as increasing the educational and cultural awareness of people. The educational support of such projects is aimed to attract the attention of the public (school and university students, science teachers and a wide interested audience) to scientific achievements. The use of modern multimedia and communication technologies for the development of projects related to the popularization of science opens great opportunities for explaining complex things in a clear and understandable form.

For years, the authors of the project participated in the creation of multimedia educational resources in collaboration with the Brookhaven National Laboratory (“Online Science Classroom” and “RHIC Lessons”), developed the Internet resource for kids – “Well of Knowledge”, prepared together with academician L.B. Okun a course of lectures for physics teachers – “Mass. Energy. Momentum”, together with Academician G.V. Trubnikov prepared a video lesson for the Russian school – “NICA Collider – the Universe in the Laboratory”.

Presentation of the video lesson for the Russian school – "NICA Collider – the Universe in the Laboratory" – at Petrozavodsk State University

In 2019, the Publishing House "Prosveshcheniye" published the textbook "Nuclear Physics", which is accompanied by models of accelerators and reactors, video lectures, and a virtual laboratory practicum.



Materials for the course "Nuclear Physics"

This project proposes to continue work in this direction, making the section of the JINR Open Educational Portal – "Scientists for Schoolchildren" – the base platform for such resources. As part of the project, it is proposed to:

- prepare new online courses for physics teachers illustrating the latest achievements of science and technology;
- expand materials on nuclear physics for school students taking into account the concerns of the JINR Member States and Associated Members (with the possibility of translation educational materials into the languages of the participating countries);
- create a base of educational materials for use in science projects and research workswithin the school physics course;
- prepare a series of popular science lectures named "Engineering – the Second History of Mankind";
- prepare lectures and workshops for Schools of physics teachers at JINR and CERN.

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5. Artemenkov D.A., Belaga V.V., Lomachenkov I.A., Panebrattsev Yu.A., et al. Teaching methodological complex ‘Physics – Spheres’ as the component of modern interdisciplinary information educational environment.
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9. D. Artemenkov, V. Belaga, I. Lomachenkov, Y. Panebrattsev, N. Vorontsova, and V. Zhumaev Hands-on Experiments and Elements of Modern Science in Course of School Physics. Proceedings of the 10 International Conference on the Hands-on Science HSCI'2013, Educating for Science and through Science. Kosice, Slovakia, p. 349.
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3.8. Reports at international conferences

1. Международная научная школа для учителей физики в Объединённом институте ядерных исследований, Дубна, 26 июня – 1 июля 2017 г.
2. the 10th Anniversary International School for Nuclear Physics “JINR Days in Bulgaria”. 16–19 May 2017. “Borovets” mountain complex, Sofia, Bulgaria.
3. The 14th annual international Conference on Hands-on Science: Growing with Science, HSCI2017. July 10 – 14, 2017. Braga, Portugal.
4. Workshop for VLab collaboration, June 30 – July 10 2017, Stellenbosch, South Africa.
5. 26-th International Symposium on Nuclear Electronics & Computing (NEC’2017), 25-29 September 2017. Montenegro, Budva, Becici.
6. The 15th annual international conference on Hands-on Science, HSCI2018, The Hands-on Science Network (www.hsci.info), Barcelona, Catalonia, Spain, 16 – 20 July 2018.
7. IX International Symposium on EXOtic Nuclei (EXON-2018), 10–15 September 2018, Petrozavodsk, Russia
8. South Africa-JINR Workshop “Virtual laboratory on detectors and signal processing” Somerset West, South Africa, 26 October – 04 November, 2018.
9. 5th Symposium «Advances and Challenges in Physics by JINR and South Africa», 4–9 November 2018. Somerset West, RSA.
10. Научная школа для учителей физики из Чехии и Словакии, 1–5 июня 2019 г. Лаборатории ОИЯИ, Дубна.
11. Международная научная школа для учителей физики ОИЯИ и Государственного университета «Дубна». 14–25 июля 2019 г., Дубна.
12. XXVII International Symposium on Nuclear Electronics & Computing, Montenegro, Budva, Becici, 30 September – 4 October 2019.
13. XII научная Школа для учителей физики из стран-участниц ОИЯИ в Европейской организации ядерных исследований, 3–10 ноября 2019 г., ЦЕРН, Женева, Швейцария.

3.9. Participation in international events: student practices, International training programs for decision-makers in science and international scientific cooperation “JINR Expertise for Member States and Partner Countries” (JEMS), exhibitions

1. IV Международная российско-сербская промышленная выставка, 14–18 марта 2017 г., г. Белград, Сербия.
2. Student Practice 2017 at JINR (I stage), 28 May – 17 June 2017, JINR, Dubna, Russia.
3. September Student Practice 2017 at JINR (III stage), 10–30 September 2017, JINR, Dubna, Russia.
4. 2nd Industrial Exhibition “EXPO-RUSSIA VIETNAM 2017”, 13–15 December 2017, Hanoi, Vietnam.
5. Practice for high-school students from Israel 2018, 11–13 April 2018, JINR, Dubna, Russia.
6. JINR Exposition at 16th Arab Conference on the Peaceful Uses of Atomic Energy, 16–20 December 2018, Sharm El-Sheikh city, Egypt.
7. Practice for high-school students from Israel 2019, 11–13 March 2019, JINR, Dubna, Russia.
8. Practice for high-school students from Germany 2019, June 2019, JINR, Dubna, Russia.
9. Practice for high-school students from Czech Republic 2019, 01 – 04 July 2019, JINR, Dubna, Russia.
10. International training programme for decision-makers in science and international scientific cooperation JEMS – «JINR Expertise for Member States and Partner Countries» – 2017–2019, JINR, Dubna, Russia.

4. Human resources

The following human resources are required to solve the tasks of the project.

1. Creation of online courses for the JINR Educational Portal

Participants:
- UC, JINR (6 FTE)
- LHEP, JINR (6 FTE)
- NRNU MEPhI (2 FTE)
- FLNP, JINR (1 FTE)
- Dubna State University (2 FTE)
- AM-MP, SPbU (1 FTE)
- Institute of Physics, KFU (1 FTE)
- North Ossetia State University (2 FTE)
- Works under R&D contracts (10 FTE)

2. Development of the project “Virtual Laboratory of Nuclear Physics»

2.1. «Virtual Laboratory of Gamma Spectrometry»
2.2. «Virtual Laboratory of Detectors and Signal Processing»
2.3. «Practicum on Data Analysis in ROOT»
2.4. Implementation of project results in the educational process at universities in Russia, the JINR Member States and the Republic of South Africa

Participants:
- FLNR, JINR (2 FTE)
- UC, JINR (5 FTE)
- Stellenbosch University, RSA (3 FTE)
- UNISA, RSA (1 FTE)
- NRNU MEPhI (1 FTE)
- Sofia University, Bulgaria (2 FTE)
- INRNEBAS, Bulgaria(1 FTE)
- University of Novi Sad, Serbia (1 FTE)
- Mongolian State University of Education (1 FTE)
- Works under R&D contracts (8 FTE)

3. Creation of hands-on practicum on nuclear physics

Participants:
- FLNR, JINR (2 FTE)
- LHEP, JINR (6 FTE)
- UC, JINR (2 FTE)
- Dubna State University (2 FTE)
- NRNU MEPhI(1 FTE)
- Sofia University, Bulgaria (1 FTE)
- INRNEBAS, Bulgaria (1 FTE)
- Works under R&D contracts (3 FTE)

4. Development of remote practicumwith the opportunity of a project work

Participants:

- Warsaw University of Technology, Poland (3 FTE)
- LHEP,JINR (5 FTE)
- UC,JINR (2 FTE)
- Dubna State University (2 FTE)
- NRNU MEPhI (1 FTE)
- Sofia University, Bulgaria (1 FTE)
- INRNEBAS, Bulgaria (1 FTE)
- Works under R&D contracts (4 FTE)

5. Development of the JINR exhibition

5.2. Exhibits about main directions of research at JINR laboratories
5.3. Popular science exhibits based on VR and AR
5.4. Creation of real models and exhibits
5.5. Interactive models of the NICA accelerator complex and MPD detector

Participants:

- FLNR, JINR (1 FTE)
- FLNP, JINR (1 FTE)
- LHEP, JINR (3 FTE)
- LRB, JINR (0,5 FTE)
- LTP, JINR (0,5 FTE)
- LIT, JINR (1 FTE)
- UC, JINR (5 FTE)
- Works under R&D contracts (12 FTE)

6. Creation of multimedia resources for physics teachers and high school students

Participants:

- LHEP, JINR (3 FTE)
- UC, JINR (5 FTE)
- Dubna State University (3 FTE)
- North Ossetia State University (1 FTE)
- Stellenbosch University, RSA (2 FTE)
- NRNU MEPhI (2 FTE)
- Works under R&D contracts (5 FTE)

5. Project budget 2021–2023

Estimation of the total budget of the project, budget per year and expenses for each of the following categories:

(a) Construction of experimental equipment for students' practicum in Dubna:
15 000 × 3 years = 45 000 $

(b) CreationofJINRexhibition (materials and equipment):
30 000 × 3 years= 90 000 $

(c) Consumables and overheads:
5 000 × 3 years = 15 000 $

(d) Costs of the salary for the project/theme participants:
9 750 000 × 3 years = 29 250 000RUB

(e) Costs of third-party contractors under the item Research&Development:
9 100 000 × 3 years = 27 300 000 RUB

(f) Financing sources (internal and external resources):

- JINR UC budget theme: 1139
- JINR infrastructure
- RSA–JINR cooperation funds
- Grants of Plenipotentiaries of JINR Member States

It is assumed that the cooperating educational organizations pay their teachers for the work related to the development of training courses and program content.

№	Expenditure	2021	2022	2023	TOTAL
1	Materials and equipment	45 000 $	45 000 $	45 000 $	135 000 $
2	Consumables and overheads	5 000 $	5 000 $	5 000 $	15 000 $
3	International scientific and technical collaboration	10 000 $	10 000 $	10 000 $	30 000 $
4	Personnel costs				
4.1.	Salary for JINR personnel: 15 FTE (9 – LHEP, 6 – UC)	150 000 $ (9 750 000 RUB)	150 000 $ (9 750 000 RUB)	150 000 $ (9 750 000 RUB)	450 000 $ (29 250 000 RUB)
4.2.	Income tax charge (Universal Social Charge)	45 300$	45 300$	445 300$	135 900$
5	Costs of third-party contractors under the item R&D 2 FTE	140 000 $ (9 100 000 RUB)	140 000 $ (9 100 000 RUB)	140 000 $ (9 100 000 RUB)	420 000 $ (27 300 000 RUB)
	TOTAL	**395 300 $**	**395 300 $**	**395 300 $**	**1 185 900 $**

6. SWOT analysis

Internal factors	External factors
Strengths	**Opportunities**
1. Professionalism of the project participants	1. Participation in a priority project "Modern digital learning environment in the Russian Federation"
2. Established connections between the universities participating in the project	2. Possibility of entering the National Open Education Platform of the Russian Federation and international platforms Coursera, edX
3. Interest in the project results on the part of all the participants	3. Use of the results obtained at JINR in the educational process at universities of Russia and JINR Member States
4. Possession of technologies for project tasks' implementation	4. Building brand awareness of JINR and NICA for a wider audience
5. 5. Availability of groundwork on all the tasks of the project	5. Increase in the number of students wishing to practice, write a thesis, enter a PhD program or work at JINR
Weaknesses	**Threats**
1. Generation of the list of online courses is in progress	1. Rapid changes in the regulations on the use of e-learning at universities
2. Rules for entering the National Open Education Platform have not been defined clearly (in progress)	2. Differences in the educational programs of Russian universities and universities of JINR Member States
	3. Force majeure

Appendix 1. Suggested list of courses

Development and support of existing online courses (edu.jinr.ru):

- Megascience project NICA (A.O. Sidorin)
- Superconducting magnets (S.A. Kostromin)
- Experimental high-energy physics (V.A. Nikitin)
- Detectors in nuclear and high energy physics (V.A. Nikitin)
- Introduction to heavy ion physics (Yu.E. Penionzhkevich)
- Lattice gauge theory (V. Braguta, A. Kotov)
- Introduction to Quantum Computation and Quantum Information (V.P. Gerdt)
- Radiation safety (G.N. Timoshenko)

Creation of online courses on JINR research topics:

- At the forefront of particle physics (D.I. Kazakov)
- Current state of nuclear theory (R.M. Jolos)
- NICA collision physics at the NICA collider (A. Kishel)
- Collisions of relativistic nuclei – fluctuations (A. Rustamov)
- Collisions of relativistic nuclei – femtoscopy (R. Lednitsky)
- Collisions of relativistic nuclei – flows (A.V. Taranenko)
- Synthesis of superheavy elements
- Neutrino physics

Creation ofonline courses on multidisciplinary applied research:

- Neutron scattering in condensed matter (A.V. Belushkin)
- Neutrons for pharmacology (N. Kucherka)
- Synchrotron and neutron studies in the field of structural biology
- Research of metals and alloys using neutrons (A.V. Belushkin)
- Methods and instruments of nuclear planetology (V.N. Shvetsov)
- Neutron activation analysis in the life sciences (MV Frontasyeva)
- Heavy ions and high technology (Yu.E. Penionzhkevich)
- Multidisciplinarity of synchrotron studies
- The use of neutrons in the study of cultural heritage
- Radiation medicine
- Radiobilogy

Information technology in experimental physics:

- Cloud and GRID technology
- Modern high performance computing technology
- Data mining methods
- Software engineering in the development of large information systems
- Technologies for the collection, storage and analysis of data in nuclear physics