Training of specialists for the implementation of the Federal Scientific and Technical Program for the Development of Synchrotron and Neutron Research and Research Infrastructure during 2019-2027

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Abstract. In 2019 a comprehensive solution to the tasks of accelerated development of synchrotron and neutron research in Russia was given by the Decree of the President of the Russian Federation. This was important for the creation of breakthrough technologies, as well as the design of the megascience class research infrastructure in our country. The network of megascience facilities by 2027 is planned to include synchrotron radiation sources in Moscow, Protvino, Novosibirsk and Vladivostok, neutron radiation source in Gatchina, huge scientific and medical centers. The head scientific organization for these significant activities became National Research Center “Kurchatov Institute”. The development, construction, operation of megascience class facilities requires large-scale training of specialists and scientific personnel in various fields (Physics of Nanosystems, Optics, Solid State Physics, Materials Science, Physical Chemistry, Electronics, etc.). The article describes the key areas of work in the field of education, which includes the mechanisms of training specialists for Federal Scientific and Technical Program for the Development of Synchrotron and Neutron Research and Research Infrastructure during 2019-2027. The plans of creation of an integrated scientific and educational community are announced.

1. General information on the implementation of the Program for the development of synchrotron and neutron research

The main regulatory legal acts governing the creation and development of research infrastructure for synchrotron and neutron research are the Decree of the President of the Russian Federation dated July 25, 2019 No. 356 “The measures to develop synchrotron and neutron research and research infrastructure in the Russian Federation” [1] and the Resolution of the Government of the Russian Federation dated March 16, 2020 No. 287 “The approval of the Federal Scientific and Technical Program for the Development of Synchrotron and Neutron Research and Research Infrastructure for 2019-2027” [2] (hereinafter - FSTP SNR or Program). According to the listed documents, 7 modern megascience class facilities located throughout Russia are planned for construction and modernization. The head scientific organization of the Program is the Federal State Budgetary Institution “National Research Center “Kurchatov Institute”.

The Program aims to provide:
• The creation of an integrated research community of users of synchrotron and neutron radiation sources.
• The distribution of research tasks, taking into account the scientific, technical and technological needs of the regions and, at the same time, the territorial integrity of country.
• The integration of a domestic scientific and research network infrastructure into the activities of the international research community.

According to the schedule of creation (modernization) of unique megascience class research facilities and complexes within the framework of the FSTP SNR the following listed in table 1 research infrastructure will be designed and developed.

Table 1 (a). Planned for creation and modernization unique megascience class research facilities.

| Name of research facility | Brief description | Location | Terms of activities |
|---------------------------|-------------------|----------|--------------------|
| SILA                      | Creation of a fundamentally new promising source, superior in technical characteristics to existing and being designed international sources of synchrotron radiation with an energy of a ring accelerator of 6 GeV, a beam current of 200 mA, a perimeter of more than 1100 m and a maximum number of stations amounted 52. | Protvino, Moscow region | 2020-2027 |
| KISI-Kurchatov            | Modernization of Kurchatov specialized source of synchrotron radiation “KISI-Kurchatov” with an energy of 2.5 GeV, a beam current of 200 mA, a perimeter of 124 m and a maximum number of stations amounted 30. | Moscow | 2020-2022 |
| OMEGA                     | Creation of a prototype of a pulsed neutron source based on an evaporative-shear-type reaction. | Protvino, Moscow region | 2020-2024 |
| RIF                       | Synchrotron radiation source design with an energy of 2 GeV, a beam current of 200 mA, a perimeter of about 120 m and a maximum number of stations amounted 30. | Russky Island, Primorsky Krai | 2020-2021 |
| Scientific and Educational Medical Center for Nuclear Medicine | Modernization of complexes of ion (carbon), proton radiation therapy, onco-ophthalmological complex and radioisotope complex for production of a wide range of medical radionuclides for diagnostics and therapy of oncological diseases. | Protvino, Moscow region | 2021-2024 |
### Table 1 (b).

| Name of research facility | Brief description | Location                  | Terms of activities |
|---------------------------|-------------------|----------------------------|---------------------|
| International Center for Neutron Research | Putting into operation (including design, construction and technical operation) of 25 research stations based on the high-flux research nuclear reactor PIK. | Gatchina, Leningrad region | 2020-2024            |
| SKIF                      | Creation of a 4+ generation synchrotron radiation source with an energy of 3 GeV, vertical / horizontal emittance of no more than 7.5 / 75 and a maximum number of stations amounted 30. | Novosibirsk region | 2020-2024            |

Such a number of large international projects of the megascience class require special integration of educational and scientific organizations to train developers, engineering personnel, technical personnel and future users of this research infrastructure.

#### 2. Training of personnel in the field of higher and secondary vocational education

The structure of the FSTP SNR includes the Activity No. 3 “Training of specialists in the development, design and construction of sources of synchrotron and neutron radiation, as well as scientific personnel for carrying out synchrotron and neutron research (development) in order to obtain world-class results”.

This Activity involves training, professional retraining and advanced training of two types of graduates: scientific personnel and specialists in the field of development, design, construction and technical operation.

Among the results of the activity No. 3 there are highlighted:

- Development and implementation of educational programs and programs of additional professional education in the field of nuclear medicine.
- Strengthening international cooperation in the creation and development of research infrastructure, training and conducting synchrotron and neutron research.

The expected number of trained specialists is given in table 2.

Nowadays only a few universities in Russia have special master's degree programs in the field of accelerator complexes. These are National Research Nuclear University MEPhI (Moscow Engineering Physics Institute) – Charged Particles Accelerators for Mega-science Class Facilities, Saint Petersburg State University – Condensed Matter Physics at MEGA-Science Facilities, Novosibirsk State University – Accelerator Physics. In this regard, the importance of mutually beneficial cooperation between scientific organizations led by the National Research Center “Kurchatov Institute” and educational institutions of higher education increases in terms of involving the research community in the design and implementation of educational modules on synchrotron and neutron research, the development of undergraduate and graduate programs, including in the format of double degree diplomas, joint organization of professional retraining and advanced training programs, development of academic mobility activities in the educational process, participation in state certification commissions and scientific supervising of final graduation theses. Among highly specialized areas that are demanded for FSTP SNR, it is necessary to highlight: the design and operation of charged particle accelerators, reactor physics and thermal physics, spectroscopy and experimental nuclear physics, radiation technologies,
collection and processing of big data, physical materials science, solid state physics, physical chemistry, etc.

Table 2. Target indicators of the Program in terms of training.

| Year | The number of specialists in the field of development, design, construction and technical operation, who are trained and employed according the area of training (cumulative total) | The number of scientific personnel, who are trained and employed according the area of training (cumulative total) |
|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| 2020 | 60                                                                                                                                                                                             | 50                                                                                                               |
| 2021 | 140                                                                                                                                                                                            | 200                                                                                                               |
| 2022 | 240                                                                                                                                                                                            | 450                                                                                                               |
| 2023 | 360                                                                                                                                                                                            | 800                                                                                                               |
| 2024 | 500                                                                                                                                                                                            | 1200                                                                                                              |
| 2025 | 600                                                                                                                                                                                            | 1600                                                                                                              |
| 2026 | 700                                                                                                                                                                                            | 2050                                                                                                              |
| 2027 | 800                                                                                                                                                                                            | 2550                                                                                                              |

It is assumed that the key mechanism for training specialists will be programs for advanced training and professional retraining in relation to synchrotron and neutron research, since their advantage is the shorter duration of study in comparison with bachelor's, master's and postgraduate programs.

It is important to note that the need for specialists in the field of development, design, construction and technical operation for FSTP SNR is not limited to graduates of higher education programs. Personnel training should also be organized via secondary vocational education programs. In this regard, in cooperation with universities, a network of colleges is being formed to jointly develop training programs for technical personnel (technicians, operators, laboratory assistants and other technical personnel), approve professional standards and formulate the basic professional competencies of specialists in the field of accelerator technology.

The process of training highly qualified specialists includes the creation of decent and attractive working conditions for them. There is under the discussion the possibility of implementing socially oriented activities, which are at the stage of students being educated:

- Additional measures of social support for students (high comfort living conditions, scholarships and grants for special success in studying).
- Creation of student scientific brigades according obtained education to work in professional area during vacation.

At the stage of graduates being employed:

- Development of a mentoring system.
- Stimulation of scientific activity and support of leading scientific schools.
- Providing accommodation for employees and their families.
- Medical care for employees and their families.
- Formation of a favorable environment for scientific creativity.
- Development of a corporate culture.
- Opportunity to continue education through postgraduate studies (postdocs programs) for employees.
These events are an integral part of creating conditions for identifying and developing talents and supporting professional growth of scientific and engineering personnel.

3. The role of secondary general education in the implementation of FSTP SNR

It is necessary to start working with future specialists and scientists already at the school level, ensuring the organization of scientific, educational and vocational guidance work to form a growing interest of schoolchildren in science in general and synchrotron and neutron research in particular.

It is possible to highlight the following mechanisms here:

- Organization of competitions of scientific works, olympiads on specific topics, hackathons under the scientific supervision of the National Research Center “Kurchatov Institute” and other leading scientific and educational organizations.
- Development and implementation of thematic shifts in children's educational centers.
- Organization of additional education programs in schools, children's technoparks, quantoriums.
- Creation of specialized laboratories (including within the framework of the Kurchatov Classes project) for schoolchildren in the regions, where the unique megascience facilities are going to be located.
- Constant search for new forms and projects in the field of education development.

The successful implementation of these activities is associated with the positioning of the “openness” of research centers and megascience facilities for students. Therefore, it is required to hold the master classes of scientists on the related topics, excursions and Open Door days in online and offline formats on a regular basis.

4. Creation of an integrated scientific and educational community

The abovementioned work in the field of secondary general, secondary vocational and higher education should be built using a single logic, ensuring interconnection and complementarity in all areas of activity. It is necessary to create conditions and a platform for the expert community to work in the field of synchrotron and neutron research. It is assumed that this will be facilitated by the functioning of the Working Group on improving the training of specialists in the development, design and construction of sources of synchrotron and neutron radiation, scientific personnel for synchrotron and neutron research (development) under the Council for the implementation of the Program, which will annually form and approve a joint plan of conferences, schools, seminars and other scientific and educational events in the areas of implementation of the FSTP SNR. The Working Group consists of the representatives of the customer-coordinator, executives in charge, co-executors, the head scientific organization and the Program participants. In addition to the National Research Center “Kurchatov Institute”, the Ministry of Science and Higher Education of the Russian Federation and the Ministry of Health of the Russian Federation, it will include representatives of leading universities from Moscow, Saint Petersburg, Arkhangelsk, Rostov-on-Don, Kaliningrad, Krasnoyarsk, Ekaterinburg, Vladivostok, Tomsk, Novosibirsk, as well as the National Association of Scientific and Educational Organizations – Participants of International Megaprojects.

Working Group from 2020 to 2021 should form:

- Recommendations on the volumes of admission quotas (AQ) and quotas for targeted training.
- Recommendations for updating educational programs of higher education and programs of additional professional education.
- Recommendations on the establishment of grants to support specialists and the implementation of programs for domestic and international academic mobility.
- Measures to promote participation in synchrotron and neutron research (development).
Within the activities performed by Working Group together with National Association of Scientific and Educational Organizations – Participants of International Megaprojects the creation of a professional community of radiation source users and organization of the work of a platform (including in the online format) for interaction, exchange of experience, updating educational programs in the field of synchrotron and neutron research are planned.

The important step for the involvement of the pedagogical community in the implementation of the FSTP SNR will be the foundation under the guidance of the NRC “Kurchatov Institute” of the Association of Teachers of Natural Science Disciplines. At the same time, within the framework of the creation of the scientific and educational space and community, the development of advanced training programs for teachers of physics, biology and natural science in the field of synchrotron and neutron research has already begun.

5. The importance of FSTP SNR for the education of the future

The implementation of the FSTP SNR is one of the key elements of the state program of the Russian Federation “Scientific and technological development of the Russian Federation”, which was approved by the Resolution of the Government of the Russian Federation dated March 29, 2019 No. 377 [3]. The critically limited time for creating an advanced research infrastructure will significantly modernize natural science education in the country, will give to the training of scientific and technical personnel a targeted focus, providing graduates with jobs for many years to come. The work of the NRC “Kurchatov Institute” in cooperation with technological partners and leading universities will become a trigger for updating the knowledge of graduates, strengthening the educational and research infrastructure of educational organizations.

The most important result of the implementation of the Program should be considered the advanced experience that ensures the technological renewal of research, scientific and technical, innovative activities, which will be taken as the basis for the implementation of projects of the same scale in the future.

References
[1] Decree of the President of the Russian Federation dated July 25, 2019 No. 356 “The measures to develop synchrotron and neutron research and research infrastructure in the Russian Federation”
[2] Resolution of the Government of the Russian Federation dated March 16, 2020 No. 287 “The approval of the Federal Scientific and Technical Program for the Development of Synchrotron and Neutron Research and Research Infrastructure for 2019-2027”
[3] Resolution of the Government of the Russian Federation dated March 29, 2019 No. 377 “The approval of the state program of the Russian Federation “Scientific and technological development of the Russian Federation”