

Project: **“Construction of a prototype of the initial section of the high-current heavy-ion linear accelerator for the production of intense radioactive ion beams for basic research”**

Supplement for the physical program of the project **“Development of the FLNR accelerator complex and experimental setups (DRIBs-III)”** on the years 2020/2021.

Theme: 03-0-1129-2017/21

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Project approval list

“Construction of a prototype of the initial section of the high-current heavy-ion linear accelerator for the production of intense radioactive ion beams for basic research”

and its supplement for the physical program of the project

“Development of the FLNR accelerator complex and experimental setups (DRIBs-III)” on the years 2020/2021.

Theme: 03-0-1129-2017/21

Theme leaders: G.G. Gulbekian, S.N. Dmitriev, M.G. Itkis

Project leaders: L.V. Grigorenko, T.V. Kulevoy

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Schedule and necessary resources for realization of the project:

“Construction of a prototype of the initial section of the high-current heavy-ion linear accelerator for the production of intense radioactive ion beams for basic research”

Supplement for the physical program of the project:

“Development of the FLNR accelerator complex and experimental setups (DRIBs-III)”

Name of works / Years	2020	2021	Total (kUSD)
Design and manufacturing of the RFQ prototype (first section)	400	330	980
Design and manufacturing of the beam transport system (CW-resonators, ion strippers, etc.)	300	220	670
Design and manufacturing of the ion beam formation system for a plasma border of the ECR ion source	80	100	240
Design of the superconducting ECR ion source 28 GHz and elements of formation system for a high current beam.	340	540	980
Design and manufacturing of the test setup consisting of ECR 14 GHz ion source and prospective LINAC front-end (LEBT, cw-RFQ etc.). Equipment test using the ions $^{14}\text{N}^{2+}$, $I \sim 30$ emA.	160	160	360
DERICA CDR. Phase 1 – project of the high current linear accelerator ($E_{\text{Ca}} \sim 140$ AMeV and $E_{\text{U}} \sim 100$ AMeV) with the downstream equipment (fragment separator, gas-cell, MR-TOF spectrometer etc.) for fundamental research with radioactive beams. Specification of scientific program for each project stage.	120	100	270
In total	1400	1450	2850

Project leader:

L.V. Grigorenko (FLNR JINR)

Estimated project costs for
**“Construction of a prototype of the initial section of the high-current heavy-ion linear
 accelerator for the production of intense radioactive ion beams for basic research”**
 and for supplement of the physical program
“Development of the FLNR accelerator complex and experimental setups (DRIBs-III)”

Cost items / Years	2020	2021	Total (kUSD)
R & D	350	350	1000
FLNR production and process department			
FLNR design department			
Equipment and materials, including: <i>RFQ sections (3 units.)</i> <i>Beam monitor system</i> <i>Vacuum system</i> <i>HV platform</i> <i>Components of ECR ion source</i> <i>RF generator, power supply,</i> <i>communications etc.</i>	970	1040	2360
International cooperation:	80	60	140
a) visit into non-JINR-member countries	60	50	
b) visit into JINR-member countries	20	10	
In total	1400	1450	2850

FLNR Director

S.N. Dmitriev

Project leader

L.V. Grigorenko

FLNR leading economist

T.V. Mamonova

Brief annotation of the project

Project DERICA (**D**ubna **E**lectron **R**adioactive **I**on **C**ollider **f**Acility, <http://aculina.jinr.ru/derica.php>) is now been considered as one of important variant of the JINR infrastructure development perspective within the next seven-year plan. The research program of the project focused on the study of radioactive nuclei is at the forefront of low energy nuclear physics. A unique feature of the project is the possibility of investigation of the electron interaction with poorly studied radioactive nuclei in collider experiments to determine the fundamental properties of nuclear matter, namely, the electromagnetic form factors of exotic nuclei. Obviously, that a number of most important and long-term R&D works should be started ASAP to provide the realization of the project during the next seven years period.

The key facility in the project is the high-intensity linear particle accelerator of heavy ions LINAC-100 with the energy of about 100 and 140 MeV/nucleon for the uranium and calcium ions, respectively. The development of the initial part of the accelerator ("front-end") is the most important and time-consuming task demanding a lot of research and development (R&D) works. The task consists of several stages and assumes the development of a set of the innovation technologies:

- development of the high-intensity ECR source of heavy ions;
- design of normal conducting LINAC sections with the RFQ focusing and drift-tubes LINACs intended to operate in a continuous (CW) mode;
- development of superconducting accelerating resonators;
- design of gas strippers to increase charge states of the accelerated ions;
- development of the RF power supplies based on solid-state amplifiers for the resonator feeding.

Development of a prototype of the initial section of the high-intensity heavy-ion LINAC is a realistic task for JINR. This confidence is based on the availability of necessary technologies in-house, existing cooperation with the leading Russian institutes (NRC KI-ITEP, NRNU MEPhI, INR RAS, VNIITE, NIIEFA), and collaboration with researchers abroad (GSI, MSU, INFN, GANIL, TRIUMF, PTI NASB). In the future, the further development of this project implies the construction of the LINAC-100 accelerator with the energy of heavy-ion beams about 100 AMeV (and higher) with record intensities ($I(\text{for U}) \sim 1 \text{ emA}$). This high-current accelerator integrated with the downstream equipment for RIB production (the fragment separator, ion gas catcher, MR-TOF spectrometer, storage ring system, etc.) will allow one to carry out unique world-level experiments with radioactive beams.

Introduction

Both, the key point and starting point on the way towards the DERICA project realization is development of the normal conducting accelerating resonators designed to operate in continuous mode. The resonators with the radiofrequency quadrupole focusing (RFQ) and several H-type resonators are needed to construct the initial part (so-called front-end) of the LINAC-100. Whereas the technologies for design and construction of the resonators operating in pulsed mode have been recovered in Russia, in particular due to the efforts of the JINR staff, the works done in Russia on the CW-resonators (Continuous Wave) are only theoretical and computational ones. It is extremely important to start designing, manufacturing and testing the prototypes of such resonators, to determine their limiting parameters, operating conditions, and start their serial production as soon as possible.

The topics of priority works and preliminary schedule are as follows:

1. Design and construction of the prototype of the new JINR basic facility in the framework of the DERICA project, aimed at fundamental radioactive ion beam research. First of all, these are:
 - (a) Design and manufacturing of the CW RFQ prototype (1-3 sections) for prospective high-intensity heavy-ion linear accelerator (with the project beam current above 1 emA).
 - (b) Development of the ion beam formation system for a plasma border of the ECR ion source and the ion beam matching system for beams generated by the ECR source with CW RFQ (LEBT - low energy beam transport).
 - (c) Development and construction of a test-stand consisting of the prototype section of the advanced CW RFQ and the 14 GHz ECR ion source. Commissioning of the equipment with the use of the $^{14}\text{N}^{2+}$ ions (for the currents of 3 emA and higher).
2. Design of the high-current superconducting ECR heavy-ion source with the 28 GHz frequency (ions up to uranium). Construction of the technology demonstrator.
3. Development and construction of the LEBT (low energy beam transport) to match the beam generated by prospective 28 GHz ECR with CW RFQ acceptance.
4. Development of the superconducting part of the LINAC-100, including of ion stripper sections and charge state separators.
5. Conceptual design report (CDR) for the whole mega-science level project DERICA.

3.4. Status of works

Development of the accelerating complex for DERICA project requires addressing a set of key scientific, engineering and technological issues. The important requirement for the subsystem's development is ensuring their reliability and stability for operation load ~ 6000 hours/year. Concerning the ion source, it is required to develop the setup (i) working in the continuous mode, (ii) providing the maximum achievable charge state of the accelerated ions (up to uranium), and (iii) delivering the highest ion beam intensity for user experiments. For the most of the experiments, the primary beam intensity should be higher than 10 pμA. Today, the heavy ion source based on electron-cyclotron resonance (ECR) is the most appropriate choice. The world record intensity values for the heavy-ion beams achieved by the best ECR ion sources are shown in the Table 1.

Table 1. Parameters of heavy-ion beams provided by ECR sources at IMP (SECRAL) and LBNL (VENUS). World-record values of intensities are emphasized by bold italics [2].

Ion, Beam	A/Z	IMP, eμA	VENUS, eμA
$^{16}\text{O}^{6+}$	2.67	6100	4750
$^{40}\text{Ar}^{12+}$	3.3	1420	1060
$^{40}\text{Ar}^{16+}$	2.5	620	523
$^{40}\text{Ar}^{18+}$	2.2	15	4
$^{40}\text{Ca}^{11+}$	3.63	710	854
$^{40}\text{Ca}^{14+}$	2.86	270	285
$^{86}\text{Kr}^{18+}$	4.78	1020	770
$^{86}\text{Kr}^{28+}$	3.07	146	100
Xe^{26+}	5.03	1100	
Xe^{30+}	4.4	320	330
Xe^{42+}	3.1	15	6
$^{209}\text{Bi}^{31+}$	6.74	680	300
$^{209}\text{Bi}^{50+}$	4.18	10	27
$^{238}\text{U}^{33+}$	7.2	202	440

Thus, it is possible to formulate the first task for R&D. It is necessary to develop the source for generation of highly charged ions beams (from boron to uranium) with the intensities close to the record ones (shown in Table 1 by bold italics), or even exceeding them. The next conclusion from Table 1 is that the front-end of the accelerator complex should be designed to accelerate ions with the mass-to-charge ratio $A/Z \leq 7.5$. The work both directions, the development of the ion source and the initial part of the accelerator complex, should be carried out in conjunction. It is necessary to develop the ion source based on the most modern technologies that should guarantee not only high-intensity beams from the source with the highest attainable charge states, but also the development of the LEBT delivering the beams with minimal phase volumes to RFQ. The parameters of the produced beam determine the construction of the beam-matching system with the accelerating structure, as well as the parameters of the accelerating channel in the initial normal conducting part of the accelerator. At present, there is excellent expertise in this field in the Russian Federation (FLNR JINR - ECR sources, NRC KI – ITEP – beam-forming systems and RFQs). With joint efforts of the above teams the expected timescale for the required developments is 3-5 years.

Within the R&D works on the front-end of the normal conducting accelerator, one should first develop the manufacturing technology of accelerating structures (RFQ and DTL) designed to operate in CW mode. Whereas the technology for the pulsed normal conducting accelerating structures has been restored in the Russian Federation within the NICA project [1], the technology for normal conducting CW-RFQ and CW-DTL still requires development. This includes the manufacturing technology of the resonator based on vacuum brazing from individual elements made of oxygen-free copper. It could provide the key parameters required for the setup operation: the residual pressure not higher than 10^{-8} Torr, the specified resonant frequency, the specified distribution of the RF field along the accelerator axis, the specified accuracy of electrode alignment, power input on the required level in continuous mode. To attain these aims, it is necessary to start work on the development of the prototype of the normal conducting part of the accelerator, namely the initial sections of RFQ, using the most recent recommendations and achievements of the global accelerator community [1-7]. It should be noted that the first part of the work, namely, the development for the accelerating structures with given electrodynamics parameters is generally solved by the world accelerator community and only adaptation of this expertise in the Russian Federation is required. However, the long-term performance of these structures under beam was achieved so-far only for small intensities of the CW beams. Thus, the search and implementation of new solutions are foreseen within this project.

Another key problem that should be resolved within this project is the general lack of high-frequency superconducting technology in Russia at present. However, this problem has already begun to be solved in the framework of joint program implemented by JINR, NRNU MEPhI, and several scientific centers at Republic of Belarus. It is assumed that by the end of this year, the first prototype of the coaxial resonator will be manufactured and its tests will start.

1. A.M. Bazanov, et al., COMMISSIONING OF NEW LIGHT ION RFQ LINAC AND FIRST NUCLOTRON RUN WITH NEW INJECTOR, Proceedings of the 8th International Particle Accelerator Conference, Copenhagen, Denmark, from 14–19 May, 2017, pp.2366-2368.
2. P. Ostroumov, Overview of Worldwide High Intensity Heavy Ion Linacs, Proceedings of the 29th Linear Accelerator Conference, Beijing, China, 16–21 September 2018.
3. P.N. Ostroumov, et al., ACCELERATOR PHYSICS ADVANCES AT FRIB, Proceedings of the 9th International Particle Accelerator Conference, Vancouver, Canada, April 29–May 4, 2018, pp.2950-2952.

4. T. Yoshimoto†, et al., ION BEAM STUDIES IN THE FRIB FRONT-END, Proceedings of the 9th International Particle Accelerator Conference, pp.1094–1096.
5. E. Fagotti, et al., IFMIF/EVEDA RFQ PRELIMINARY BEAM CHARACTERIZATION, Proceedings of the 29th Linear Accelerator Conference, Beijing, China, 16–21 September 2018, pp.834-837.
6. E. Pozdeyev, et al., FIRST ACCELERATION AT FRIB, Proceedings of the 29th Linear Accelerator Conference, Beijing, China, 16–21 September 2018, pp.615–619.
7. M. Sugimoto, et al., PROGRESS REPORT ON LIPAC, Proceedings of the 29th Linear Accelerator Conference, Beijing, China, 16–21 September 2018, pp.308-313.

3.5. Description of the proposed project (no more than 5 pages).

The purpose of the work is the development of technical base for the construction of the heavy-ion accelerator designed for energy about 100 AMeV, LINAC-100, which is the beam driver for the DERICA facility. At the first stage, it is suggested to develop and construct the ECR ion source using superconducting magnets and operating at frequency 28 GHz, as well several sections of the prototype RFQ, for the R&D works on continuous-mode operation. Along with the solution of these key tasks, the test stand of the accelerator front-end will be developed including the high-voltage platform with the installed test ECR source, the ion beam-forming system, the beam transport and matching with the RFQ acceptance. The test-stand will be equipped with a diagnostic system for the ion beam, which will also be developed and constructed in the course of the project.

The following results of the works are expected:

1. Basing on beam dynamics simulations the accelerating LINAC-100 channel from the ion source to the LINAC-100 output will be developed. The RF operation frequency range of the accelerator resonators will be defined, the energy of shift from one frequency to another will be selected, and the quantity, design and installation points of the ion strippers will be chosen.
2. The technical documentation for the 28 GHz ECR source with the superconducting magnets will be developed.
3. The technical documentation will be developed and several first sections of RFQ of the initial part of the LINAC-100 accelerator will be manufactured.
4. The test-stand for testing under beam will be constructed to verify the physical, technological and design solutions for the beam-forming system, the beam transport channel, and low-energy beam matching with the RFQ acceptance, the RFQ design.
5. Deeper specification of the scientific program, feasibility studies and following CDR development for the whole DERICA project is expected.

The general trends of the accelerator technique development in the world are:

1. The ion sources are used based on the electron-cyclotron resonance (ECR) operating with superconducting magnets [1],[2];
2. Development of systems with the radiofrequency quadrupole focusing (RFQ) [3] functioning in the continuous mode. These systems are used for bunching and acceleration of a beam in the initial part of the accelerating complex up to energies of several MeV, provide possibility of low-energy (down to several tens of keV) injection of ion beam and allow for high (close to 100 %) beam transmission efficiency. Today in the world, the technology of creation of CW-RFQ is still under development There are already

examples of the operating CW-RFQ but so far working with beams of negligibly small intensity [4];

3. For the energy range of 3-50 MeV the phasing out the use of the classical Alvarez accelerator is observed. Instead systems based on the IH-type resonators with the radio-frequency (RF) transverse focusing, or systems consisting of acceleration sections based on the IH-type resonators and focusing elements [5,6] are more often used. As well, the separate short IH-type resonators (CH, a quarter - and half-wave resonators, spoke resonators, etc.) with the focusing solenoids and quadrupole lenses placed between the resonators are used;

4. At intermediate and high energies the superconducting resonators are used in accordance with the modular design principle for accelerators: the superconducting resonators are divided into few groups of identical resonators. Such approach significantly simplifies and decrease the cost of the manufacturing process;

5. The superconducting sections are started using at as low as possible energies. Whereas in the SNS accelerator the superconducting sections operate starting from the energy of 186 MeV, in the linear particle accelerator of the MYRRHA sub-critical facility it is planned to use them starting from 5.5 MeV. This allows to significantly simplify and, as a result, to lower the cost of the accelerator RF power supply system and also to reduce the cost of its operation. In the Legnaro National laboratory (LNL-INFN, Italy) with participation of staffs of the National Research Center "Kurchatov Institute" – ITEP the first-ever superconducting accelerator with the radiofrequency quadrupole focusing [7], has been put into operation. However such cardinal solution does not look reasonable in view of technical difficulties which complicate achievement of the demanded beam transmission efficiency for an intensive beam;

6. Solid-state powerful RF power supply. Reliability and life-time of the RF power supply of this type are much higher, than those for the traditional vacuum power RF tubes of comparable power [8], [9].

To develop and construct accelerator LINAC-100 a number of challenges must be addressed, main of them are:

1. Optimization of the accelerator general layout, including bends, strippers and separators, securing the variation of parameters for the acceleration of ions with the different charge-to-mass ratio keeping the particle loss in the superconducting part at a level of not more than 10^{-4} m^{-1} . It is also necessary to optimize the stripper position in order to reduce the number of needed superconducting resonators and, respectively, decrease the LINAC-100 cost. The work will be carried out by the working staff of NRNU MEPhI, National Research Center "Kurchatov Institute" - ITEP, GSI (Germany) with participation of specialists from LNL-INFN (Italy). Specialists of JINR determine the initial and final parameters of ion beams received with the ECR source which are necessary for experimental works at the output of the accelerator.

2. Generation and forming of ion beams with the highest charge state and intensity not less than 10 pA with the normalized emittance not higher than 1-2 $\pi \text{ mm mrad}$ at the level 98% of the intensity. To solve this problem it is necessary to develop and construct the ECR source with the superconducting magnet system operating at the frequency of 28 GHz. This work is carried out by group of specialists from FLNR JINR. The aim of the work is, at least, to provide generation of the beam of uranium ions in charge state not less than 33+ having intensity not less than 10 pA, compatible with the world-best achieved results, intending to improve these parameters further.

3. System shaping the beam with emittance not worse than 1–2 $\pi \text{ mm mrad}$ has to be developed for this source. This work can be started along with development of the ECR source prototype with the use of the KOBRA-3D software package. The work will

be carried out in cooperation with experts from FLNR JINR and National Research Center “Kurchatov Institute” – ITEP being familiar with the KOBRA-3D software package and having experience in R&D work on forming systems for the ion beams with plasma border [13];

4. Creation of a test stand, equipped with the required diagnostic tools, for checking the ECR source, the low-energy channel of the beam transport, and the RFQ resonators “in-beam”. The work will be performed in collaboration by the experts of FLNR JINR, National Research Center “Kurchatov Institute” – ITEP and INR RAS. FLNR JINR is responsible for the construction of the HV platform and a test ion source, and also FLNR JINR, together with ITEP, will develop elements of the beam-transportation channel. The working staff of ITEP participates in the development of elements of the diagnostic system, in particular, the beam transformer for a continuous beam, the emittance measuring instrument, where they have extensive experience, including joint works with JINR [10], [11], [12]. INR RAS develops the detector for the bunch shape measurements (Bunch Shape Monitor) [14].

5. Development of the low-energy beam transport for six-dimension matching with the RFQ. The magnetic separator, the focusing lenses (solenoids or quadrupoles) and RF buncher for the longitudinal matching of the beam will be in the composition of the channel [15]. The development of the channel will be performed by group of experts from FLNR JINR (magnetic elements), National Research Center “Kurchatov Institute”- ITEP (HF buncher). Manufacturing of the channel elements is supposed to be carried out with involvement of the enterprises of Rosatom – NII-EFA (St.-Petersburg) and VNIITF (Snezhinsk);

6. Development of the manufacturing techniques and setup of the RFQ resonators, maintenance of stability of their parameters during the work in the CW mode. For doing this, several sections of RFQ will be developed and tested. At the first stage, the manufacturing techniques of these sections will be developed, providing a working vacuum pressure not worse than 10^{-8} Torr, adjustment of electrodes, and achievement of the required electrodynamic parameters of resonators. At the second stage, RFQ will be installed on the test stand for matching of the emittance of the ion beam with acceptance of RFQ, testing of correctness of the chosen parameters for the resonators providing stability of work of RFQ under beam, measurement of the beam parameters at the RFQ exit. Development of sections will be carried out by group of specialists from National Research Center “Kurchatov Institute” – ITEP, in collaboration with experts from NRNU MEPhI, INR RAS (Troitsk), GSI (Germany) and LNL-INFN (Italy);

7. Development of the RF generators operating in the CW mode. In Russian Federation, NIITFA of Rosatom State Atomic Energy Corporation and “Triada-TV” company (Novosibirsk) are engaged in development of the solid-state generators. When the RFQ resonators are ready, the agreement should be signed with one of these companies for delivery of the corresponding modules. The work will be fulfilled under the control of the National Research Center “Kurchatov Institute” – ITEP;

8. Development of the ion beam acceleration channel on the basis of simulated beam dynamics for defining and optimization of amount of the superconducting resonators needed for the acceleration of a broad range of ions. Simulation of the beam dynamics in the superconducting part of the accelerator will be carried out by group of specialists from NRNU MEPhI, development of resonators is performed in collaboration of specialists from NRNU MEPhI, JINR, number of institutes of Republic of Belarus, with involvement of specialists from GSI (Germany), LNL-INFN (Italy), TRIUMF (Canada);

9. A study of electrodynamic parameters and mechanical loads in the superconducting resonators in the transition processes. This work will be carried out when the superconducting resonators are ready. The work is already performed by the joint team of experts from NRNU MEPhI, JINR, number of institutes of Republic of

Belarus with involvement of experts from GSI (Germany), LNL-INFN (Italy), TRIUMF (Canada) and financed from other sources.

It is supposed that the work will take at least two years.

During the first year, the development of the channel of the LINAC-100 accelerator from the ion source to the exit from the superconducting part of the accelerator will be complete. The stripper positions and the general structure of the separators placed after strippers will be defined. The chain of frequencies of the resonators will be defined, energies of the operating frequencies shift and also the place of transition from normal conducting part of the accelerator to the superconducting one will be fixed. The works on simulation of the electrodynamics parameters of the RFQ resonators as well as the thermal calculations of these resonators will be performed. Basing on these results, the design documentation (DD) on production of the RFQ resonator prototype will be provided. The technical specification on the 28 GHz ECR source with superconducting magnets will be provided. The technical project of the test stand will be developed. DD on the basic elements of the beam diagnostic system will be prepared. The design documentation on the buncher for the longitudinal matching of the beam will be developed.

During the second year, the DD on different parts will be prepared and delivered for manufacturing; architectural supervision of their production will be overseen, with acceptance as the products are ready. The works on preparation of the place for the test stand will be performed and the parts will be mounted as they are ready. Basing on the numerical simulations of the beam-forming system for the test source, DD will be developed and the manufacturing will be started.

The works on production of the first test resonator will be completed. The testing and tuning of the resonator together with putting it under operation at the working HF power level will be fulfilled. According to the results of testing the resonator DD will be corrected and manufacturing of the corrected modifications will be started. The test stand will be assembled and the testing ECR source with the developed beam-forming system will be installed. The beam diagnostic system will be mounted and tested. The works on ion beam source measurement and optimization will be carried out. The channel of the ion beam transportation to the place of its input to RFQ will be mounted. The works on tuning of the channel to match the beam emittance to the RFQ acceptance will be carried out. Input of a beam to RFQ will be carried out.

During two years, the works on the feasibility of the DERICA project [16] with involvement of experts from NPI (Novosibirsk), IAP RAS (. St. Petersburg), NRNU MEPhI, National Research Center "Kurchatov Institute" -ITEP (Moscow), GSI (Germany), MSU (USA), Nihon Univ. (Japan) will be conducted with corresponding development of the conceptual and technical design of the project. Deeper specification of the scientific program is foreseen too.

References

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3.6. Staff estimation.

The total number of experts involved into the project now is expected to be 17 persons per year (i.e. equivalent of full working time).

Personally, employment of each institute is presented in the Table 2.

Table 2. Estimation of the involved staff into the main works of the project.

Name of works	Institute	Employees / employment (%)	Equivalent of full employment (persons/year)
Construction of the test stand consisting of ECR ion source and LINAC front-end; design of the ECR ion source with 28 GHz frequency; conceptual design report for DERICA project	JINR NIIIEFA BINP IAP RAN NRC KI – ITEP MEPhI	12 / 25 2 / 25 8 / 25 1 / 30 2 / 25 1 / 20	26/4=6.5
Design and manufacturing of the CW RFQ prototype and ion beam formation system for a plasma border of the ECR ion source (low energy beam transport line)	JINR NIIIEFA INP RAN VNIITF VNIEEF NRC KI – ITEP	2 / 25 2 / 25 4 / 25 4 / 25 2 / 25 8 / 25	22/4=5.5
Design and manufacturing of the superconductive part of LINAC (prototypes including CW resonators, ion strippers etc.)	JINR INP RAN MEPhI NRC KI – ITEP PTI NASB	2 / 25 2 / 25 7 / 25 1 / 25 4 / 25	16/4=4.0
Specification of the scientific program per each stage of the DERICA project	JINR BINP KI NIIYaF MSU	5 / 10 1 / 10 2 / 10 2 / 10	10/10=1
			In total: 17