APPROVED

JINR DIRECTOR

_____/_____

"____"202г.

PROJECT PROPOSAL

Opening/renewal of a research project/subproject of the large research infrastructure project within the Topical plan of JINR

1. General information on the research project of the theme/subproject of the large research infrastructure project (hereinafter LRIP subproject)

1.1 Theme code / LRIP

02-1-1065-2007/2026

1.2 Project/LRIP subproject code (for extended projects)

02-1-1065-1-2011/2024

1.3 Laboratory

VBLHEP

1.4 Scientific field

Large research infrastructure project

1.5 Title of the project/LRIP subproject

Nuclotron-NICA

1.6 Project/LRIP subproject leader(s)

A.V. Butenko
H.G. Khodzhibagiyan

1.7 Project/LRIP subproject deputy leader(s) (scientific supervisor(s))

Scientific leader: I.N. Meshkov

2 Scientific case and project organization

2.1 Annotation

The main goals of the NICA project are the design and construction of the complex of accelerators, collider and physics experimental facilities at extracted and colliding ion beams aimed at studying dense baryonic matter and the spin structure of nucleons and light ions, and at carrying out applied and innovation projects.

TomeetthesegoalstheNICAcomplexwillincludethefollowingmainelements:
- injectioncomplexincludingcryogenicheavyionsourceKRION oftheelectronstringtype, source of polarized proton and deuteron beams, modernized linear accelerator LU-20, new linear heavy ion accelerator HILAC, new light ion accelerator LILAC,
- superconducting synchrotron Booster,
- modernized superconducting synchrotron Nuclotron,
- collider consisting of two superconducting rings with two interaction points,
- transportchannelsforheavyandlightions, polarizedbeams, experimentalstations for innovation and applied researches and required infrastructure.

Besides that, the project realization presumes required development of the VBLHEP cryogenic complex, development of the system for management and development of the laboratory infrastructure.

In the fames of the Seven-year plan for the development of JINR for 2024–2030 the R&D, prototyping, testing, magnet production for the "new" Nuclotron ring are providing.

2.2 Scientific case (aim, relevance and scientific novelty, methods and approaches, techniques, expected results, risks)

The aims of the Nuclotron-NICA project are:
- commissioningoftheNICAcomplexobjectsatbasicconfigurationofthecolliderequipment,
- prolongation of the experiments at fixed targets with heavy ion and light nuclei polarized beams,
- start the experiments at colliding beams,
- R&D, prototyping, testing, pre-serial magnet production for the "new" Nuclotron ring.

The elements of the complex are created on the basis of the following document approved on December 28, 2018:

TECHNICAL PROJECTOF THE OBJECT "NICA COMPLEX"

Section: TECHNICAL SPECIFICATION(PASSPORT)

OF THE "NICA COMPLEX"OBJECT

available at the web-site **https://nica.jinr.ru/documents/TDR_spec_Fin0_for_site_eng.pdf.**

Specifications of the objects developing or creating in the frame of the Nuclotron-NICA project are presented in the following chapters:
2. Accelerator unit
6. Innovation unit
8.2. Cryogenic infrastructure
8.4. High-tech assembly and testing line of SC magnets

To meet the project goal one plans the development and carryout works on of the existing infrastructure of the VBLHEP accelerator complex: HILAC, Booster, Nuclotron, beam transport lines in bldg. 1, bldg. 205 and new building 17 and other systems and new equipment required for the NICA collider commissioning at project equipment configuration in 2027.

Beforetheprojectcompletion,thecommissioningofthefollowingelements is scheduled:
- beamtransportlinefromtheNuclotron to collider,
-the collider at basic configuration of the equipment.
The works aimed to creation of the light ion linear accelerator LILAC will be prolonged.

Delayfromthe scheduleoftheprojectduring 2021 – 2024 iscausedmainlybydelaywithdeliveryoftheengineering equipment of the collider building and equipment of the collider itself.

Until December 2023, General Contractor of the collider building construction was the Strabagcompany from Republic of Austria. A triliteral agreement between JINR and two companies - Strabag and TavridaEnergostroy - on assignment of rights and transfer of obligations is being concluded. TavridaEnergostroy will be the new General Contractor. That agreement must be completed in December 2024.

The undelivered equipmentofthecolliderisunderconstructionatRussian companies.
TheproblemwithtransportationoftheLILACequipmentfromGermany is not resolved yet.
Toprovidetheexperimentalprogramwithpolarizedbeamstheworksfor performance improvement of the existing accelerator LU-20 are carrying out.
The collider commissioning at the project configuration depends on delivery of a few systems. However these systems are not critical for the collider operation at the basic configuration with colliding heavy ion beams up to Bi^{+83}at the luminosity not less than $L = 10^{24}cm^{-2}s^{-1}$and energy from $\sqrt{s_{NN}} = 4$ GeV/u.

Commissioning of the collider will be provided in the following stages:
- experiments with circulating heavy ion beams at the kinetic energy up to 2 GeV/n with internal target and colliding beams – 2025,
- commissioning of the beam cooling systems, increase of the stored beam intensity 2026,
- gradual increase of the colliding beam energy and luminosity – 2027.

Fundingprofileandcontrolofitsrealizationareprovidedusingspecializeddatabases ADB2 andNICAEVM.

2.3 Estimated completion date

2027

2.4 Participating JINR laboratories

DLNP, MLIT

2.5. Participating countries, scientific and educational organizations

Presented in the Topical plan 2024 at the pages 21 – 24

3. Manpower

3.1. Manpower needs in the first year of implementation

№№ n/a	Categoryofpersonnel	JINR staff, amount of FTE	JINR Associated Personnel, amount of FTE
1.	Researchscientists	54 (50,8)	3 (3)
2.	engineers	245 (240,38)	
3.	specialists	18,0 (17,5)	
4.	officeworkers	25 (25,0)	
5.	technicians	55 (54,0)	
	Total:	**397 (387,68)**	

4. Financing

4.1 Total estimated cost of the project/LRIP subproject

The total cost estimate of the project (for the whole period, excluding salary).
The details are given in a separate table below.

35 900 k$

4.2 Extra funding sources
Expected funding from partners/customers – a total estimate.

2 200 k$

Project (LRIP subproject) Leader Butenko A.V.

Date of submission of the project (LRIP subproject) to the Chief Scientific Secretary: _____

Date of decision of the laboratory's STC: 09.04.2024 document number: _____

Year of the project (LRIP subproject) start: _____

(for extended projects) – Project start year: 2011

Proposed schedule and resource request for the Project / LRIP subproject

Expenditures, resources, funding sources			Cost (thousands of US dollars)/ Resource requirements	Cost/Resources, distribution by years		
				1st year	2nd year	3rd year
		Internationalcooperation	900	300	300	300
		Materials	10500	3900	3300	3300
		Equipment, Third-party company services	18500	7500	5500	5500
		Commissioning	2100	780	660	660
		R&D contracts with other research organizations	3500	1300	1100	1100
		Softwarepurchasing	400	150	150	100
		Design/construction	-	-	-	-
		Service costs (*planned in case of direct project affiliation)*	-	-	-	-
Resourcesrequired	**Standardhours**					
		Accelerator	2900	800	900	1200
Sourcesoffunding	**JINR Budget**		35900	13930	11010	10960
	Extrafudning (supplementaryestimates)		2200	2200	-	

Project (LRIP subproject) Leader _____ Butenko A.V

Laboratory Economist _____ / ЛАЗАРЕНКОВА К.А.

APPROVAL SHEET FOR PROJECT / LRIP SUBPROJECT

TITLE OF THE PROJECT/LRIP SUBPROJECT

SHORT DESIGNATION OF THE PROJECT / SUBPROJECT OF THE LRIP

PROJECT/LRIP SUBPROJECT CODE

THEME / LRIP CODE

NAME OF THE PROJECT/ LRIP SUBPROJECT LEADER

AGREED

	SIGNATURE	NAME	DATE
JINR VICE-DIRECTOR			
CHIEF SCIENTIFIC SECRETARY			
CHIEF ENGINEER			
LABORATORY DIRECTOR		Butenko A.V.	
CHIEF LABORATORY ENGINEER		N. Agapov	11.04.2024
LABORATORY SCIENTIFIC SECRETARY		a.chepurnov	11.04.2024
THEME / LRIP LEADER			
PROJECT / LRIP SUBPROJECT LEADER		Butenko A.V.	
Scientific leader I		Meshkov O.I.	11.04.2024

APPROVED BY THE PAC

SIGNATURE	NAME	DATE

PROJECT REPORT

1. General information on the project / LRIP subproject

1.1. Scientific field

Large JINR Research Infrastructure

1.2. Title of the project / LRIP subproject

Nuclotron-NICA

1.3. Project (LRIP subproject) code

02-1-1065-1-2011/2023

1.4. Theme / LRIP code

02-1-1065-2007/2026

1.5. Actual duration of the project/ LRIP subproject

2011 - 2024

1.6. Project / LRIP subproject Leader(s)

A.V. Butenko
H.G. Khodzhibagiyan
Scientific leader: I.N. Meshkov

2. Scientific report

2.1. Annotation

The main goals of the Nuclotron-NICA project for the period of 2021 to 2024 have been:
-completion of the accelerator complex construction,
- carrying out commissioning works at the collider with the starting configuration of the equipment,
- completion of the collider construction in the basic configuration.

The main parts of the accelerator complex, which still need tobe completed for the starting configuration are:
- an upgrade of Nuclotron beam injection and an addition of single turn extraction from Nuclotron (to the collider),
- Nuclotron-to-collider beam transport lines,
- completion of the collider in starting configuration,
- completion of experimental stations and beam lines to the targets of beam physics experiments and applied science, and the corresponding infrastructure,

- lightionlinearacceleratorLILAC,
- completion of the cryogenic complex upgrade.

Commissioning of the NICA injection complex was recently completed. The complex includes the heavy ion source KRION-6T, heavy ion linear accelerator HILAC, superconducting synchrotron-Booster, modernized Nuclotron and corresponding beam lines. BM@NandARIADNA collaborations started experimental work.

Thus,the 1st stageofthemega-scienceprojectNICAwascomplete in 2023; i.e.thecolliderinjectioncomplexwascommissioned, experimentalresearchat the BM@N detector wasstartedusing the slowextracted Nuclotron beam with the planned project configuration.

The following main results are expected totheendof 2024:

- vacuum and cryo-magnetic tests of the collider,
- readiness for collider commissioning with circulating beams in 2025.

The delay from the project schedule was determined mainly by delays in the collider building construction, the delivery of equipment of the Nuclotron-to-Collider beam transport line and the light ion linac (LILAC).

2.2. A detailed scientific report

2.2.1. A description of the research undertaken and the results obtained.

Intheperiodfrom 2021 to2023the following main results were obtained:

- Construction, assembly and test of the elements of the Booster fast extraction system and the Booster-Nuclotron beam transport line were completed (Fig. 1).

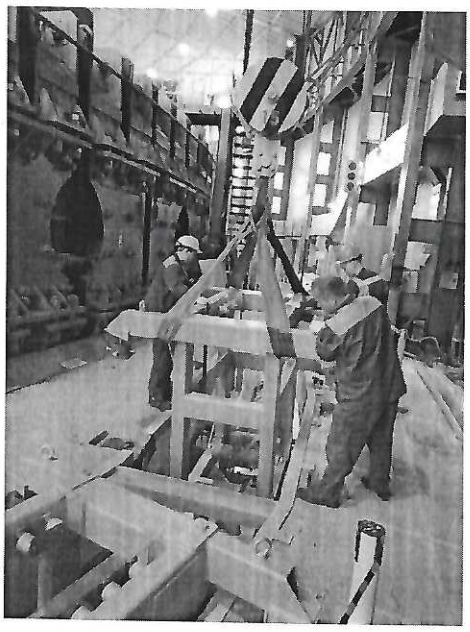

Fig. 1. Elements of the Booster-Nuclotron beam transport lineduring assembly.

- Intheperiodfrom 06.09 to 23.09.2021 thesecondcommissioningrunwasperformed. Itsmaingoalwasa testofthe fastbeamextractionfromtheBoosterandthe Booster-to-Nuclotron beamline. DuringthisrunHe^{2+}

ionsfromtheplasmasourceandFe^{14+}fromthelasersourcewereaccelerated.
Thefollowingmainworkswerecomplete:
- the residual gas density was estimated via measurements of the helium ion life-time during the beam circulation at injection energy. Average pressure of the residual gas of $4 \cdot 10^{-9}$Pa was achieved. That is sufficient for heavy ion acceleration,
- theRFacceleratingsystemwastuned. TheFe^{14+}ionswereacceleratedupto 578 MeV/u with change of the harmonic number at intermediate plateau of the magnetic field,
- electroncoolingoftheironbeam at the injection energy was demonstrated,
- acceleratedironbeamwasextractedfromtheBooster and transported through the beam line to the entrance of the Nuclotron (Fig. 2).

Fig. 2. Ironbeamspotattheluminescentscreenattheexitofthe Booster-Nuclotron beam line.

- Modern power supply system for the extracted beam line magnets was installed and commissioned (Fig. 3).

Fig. 3. Powersupplyunitsformagneticopticelementsoftheextractedbeamlines.

- Intheperiodfrom 06.01 to 01.04.2022 thethirdcommissioningrunwasperformed. Carbonionsfromthelasersourcewereacceleratedtotheenergyof3GeV/u in the Nuclotron. Thefollowingmainworkswereconsequently accomplished:
- coolingdownandmaintaining the operating temperatureofbothringswereperformedforthefirsttime at the NICA injection complex,

- ionstrippingstationlocated inside the Booster-to-Nuclotron transport line wascommissioned,
- beaminjectionintotheNuclotron, accelerationandslow extraction with spill duration up to 6 s were tuned,
- stableoperationofthecomplexduring 24 dayswassupported. In addition to the commissioning of the injection complex the beam was delivered to theSRC experiment.

Duringthefourthcommissioningruncarried outfrom 20.09.22 to 03.02.2023 the collider injection complex was operated in the complete configuration: heavy ion source KRION-6T, HILAC, Booster and Nuclotron. Modernizationofthevacuumsystemoftheextracted beam lines was completed. Theelementsofnewbeamdiagnosticsystemweretested. The argon and xenon ions were accelerated. The xenon beam at energy of 3.9 GeV/u was delivered to BM@N experiment and for support of ARIADNA collaboration program. Booster electron cooling system was tuned resulting in the cooling time closed to the design value (Fig. 4).

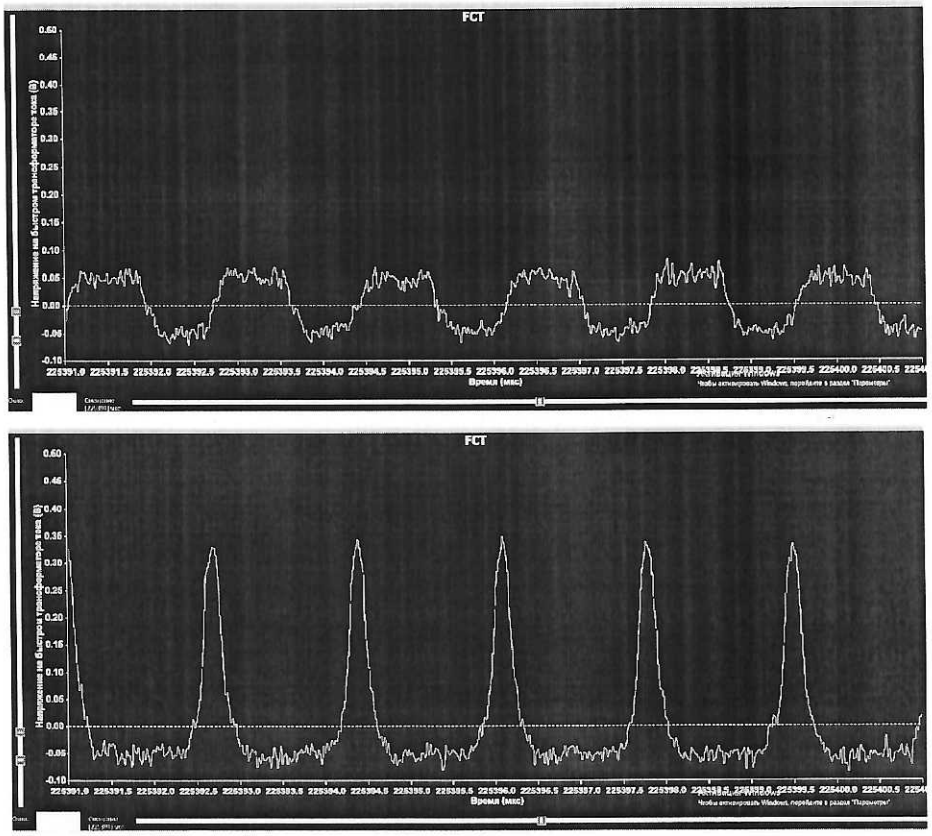

Fig. 4. Dependence of beam current on time forthexenonbeammeasuredbythe fastcurrenttransformer at the end of cooling cycle: withoutcooling – upperplot, withcooling – downplot. The cooling time is about 100 ms.

- AssemblyoftheequipmentoftheSOCHI, SIMBOandISKRA stations dedicated to the appliedresearch program was completed. AttheSOCHIstationtheexperimental program was started (Figs. 5, 6).

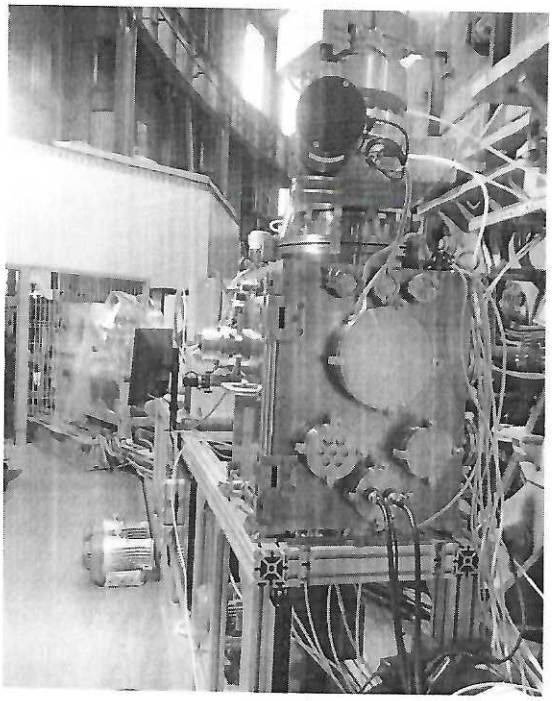

Fig. 5. 22 – 23 Decemberof 2021 - testoftheSOCHIstationequipmentwiththecarbonbeamatthe 3.2 MeV/u kinetic energy.

Fig. 6. Januaryof 2024 – assembly of the SIMBO and ISKRA stations iscompleted.

- PreparationoftheNICAcollidersystemsfor technological run scheduled for the end of 2024 is in the final stage.

Expected development of the NICA project in 2024:

1. The efforts will be aimed at further improvements of the HILAC, Booster and Nuclotron, as well as the existing beam transport lines in buildings 1 and 205. The major goal for the rest of year will be an assembly of the collider start configuration and the Nuclotron-Collider beam transport line in the building 1 and the new building 17 and their commissioning, as well as an assembly and commissioning of the fast extraction from Nuclotron, an assembly and commissioning of beam

injection and the beam extraction from the Collider to its beam dump. Further development of the existing infrastructure for applied research with heavy ion beams. Preparation for the acceleration complex run in 2025.

2. Preparation of the cryogenic complex for machine commissioning scheduled to start in the end of 2024. The upgrade of the cryogenic includesan addition of two Collider refrigerators in new building 17 and the nitrogen system. The latter will allow us to operate with the closed nitrogen cycle supporting cooling to the liquid nitrogen temperatures with much lower operating cost

2.2.2. A list of the main publications of the JINR authors, including associated personnel on the results of the project (list of bibliographical references).

Duringtheperiodfrom 2021 to2024the JINR authors prepared 156 publications including
- 36publications in scientific journals,
- 87 conference reports.

Main publications:

1. Yu.N. Filatov, A.M. Kondratenko, M.A. Kondratenko, V.V. Vorobyov, S.V. Vinogradov, E.D. Tsyplakov, A.V. Butenko, E.M. Syresin, S.A. Kostromin, Ya.S. Derbenev, Numerical modeling of a proton spin-flipping system in the spin transparency mode at an integer spin resonance in JINR Nuclotron, Journal of Instrumentation, ISSN:1748-0221, № P12039, 2021

2. Kostromin, S.Sidorin, A., Heavy ion collider NICA at JINR, Journal of Instrumentation; ISSN 1748-0221; v. 16(03); [12 p.], 2021.

3. Melnikov S.A., Meshkov I.N., Impedance Budget of the NICA Collider Ring, Physics of Particles and Nuclei Letters, ISSN:1547-4771, eISSN:1531-8567, Изд:MAIK Nauka/Interperiodica, V. 19, 2022

4. Filatov G., Slivin A., Syresin E., Butenko A., Vorozhtsov A., Agapov A., Shipulin K., Kolesnikov S., Karpinskii V., Kuznetsov M., Kirov S., Sergeev A., Galimov A., Tikhomirov A., Tyulkin V., Letkin D., Leushin D., Tuzikov A. Progress on New Beam Lines Design and Construction for Applied Research at NICA // Phys. Part. Nucl. Lett. 2022. V. 19, No. 5. P. 513.

5. A.Yu. Grebentsov, O.I. Brovko, A.V. Butenko, et. al., Booster RF System First Beam Tests, the Joint Accelerator Conferences Website Publishing, JACoW-RuPAC2021-WEPSC14, 2021.

6. M. Bazanov, A. V. Butenko, B. V. Golovenskiy, et. al., Light-Ion Linear Accelerator for the NICA Project, Physics of Particles and Nuclei Letters, 2020, Vol. 17, No. 4, pp. 481–487.

7. A.V. Butenko, O.I. Brovko, A.R. Galimov, E.V. Gorbachev, S.A. Kostromin, V.N. Karpinsky, I.N. Meshkov, V.A. Monchinskiy, A.O. Sidorin, E.M. Syresin, G.V. Trubnikov, A.V. Tuzikov, A.V. Philippov, H.G. Khodzhibagiyan, NICA Booster: a new-generation superconducting synchrotron, UspekhiFizicheskikhNauk 193 (2) 206 - 224 (2023)

2.2.3. A complete list of publications (electronic annex).

2.2.4. List of talks given at international conferences and meetings (electronic annex).

2.3. Results of related activities

2.3.1. Research and education activities. List of defended dissertations.

On results of the project 7 masterdiplomawere preparedatMEPhI, SPbSU, IUD,

2 candidatethesis were defended:

A.V.Tuzikov, «Heavy ion beam injection into the NICA Booster», 16.02.2023

K.A.Levterov, «Formation of accelerated ion beams at heavy ion injector of the NICA complex», 2.03.2023

2.3.2. Awards and prizes.

JINR prizes:

2021 First prize"Construction of the NICA Booster"
2022 Firstprize"Creation of systems of ion beam transfer to the Booster and Nuclotron synchrotrons of the NICA accelerator facility"

VekslerprizeofRAS:

2024 «Multifunctionalheavyionacceleratorcomplex – injectoroftheNICAcollider»

3. Participating countries, scientific and educational organizations

Presented in the Topical plan 2024 at the pages 21 – 24

4. Analysis of planed vs actually used resources: manpower (including associated personnel), financial, IT, infrastructure

4.1 Manpower (actual at the time of reporting)

№№ n/a	Categoryofpersonnel	JINR staff, amount of FTE	JINR Associated Personnel, amount of FTE
1.	Researchscientists	54 (50,8)	3 (3)
2.	engineers	245 (240,38)	
3.	specialists	18,0 (17,5)	
4.	officeworkers	25 (25,0)	
5.	technicians	55 (54,0)	
	Total:	**397 (387,68)**	

4.2 The actual estimated cost of the project/ LRIP subproject

Names of costs, resources, funding sources			Cost (thousands of US dollars) / Resource request
		Internationalcooperation	3 900,0
		Materials	30 340,0
		Equipment, Third-party company services	113 511,0
		Commissioning	82,8
		R&D contracts with other research organizations	6 331,2
		Softwarepurchasing	466,7
		Design/construction	192,5
		Service costs (*planned in case of direct project affiliation)*	
Resourcesrequired	**Standardhours**		
Sourcesoffunding	**JINR Budget**		154 824,2
	Extrafudning (supplementary estimates)		61 410,1

5. Conclusion

During 2021-2024 I stage of the mega-science project NICA was realized:

- injection complex of the collider was created including heavy ion source KRION-6T, HILAC, Booster, Nuclotron,
- the program of fundamental and applied researches was started at fixed targets.

The commission works were not completed at the following elements of the accelerator complex:

- beam transport line from Nuclotron to collider,
- basic configuration of the collider equipment,
- light ion linear accelerator LILAC.

The delay from the project schedule was determined mainly by delays in the collider building construction, delivery of the equipment of the beam transport line from Nuclotron to collider and elements of the LILAC.

6. Proposedreviewers

B.Yu.Sharkov, G.D.Shirkov

Theme / LRIP Leader

_____/_____/

"_____"_____ 202_г.

Project leader (project code) / LRIP subproject

_____/ Butenko A.V.

"_____"_____ 202_г.

LaboratoryEconomist

_____/ ЛАЗАРЕНКОВА А.А.

"_____"_____ 202_ г.

ВЫПИСКА ИЗ ПРОТОКОЛА
заседания НТС ЛФВЭ
от 09 апреля 2024 года

Присутствовали на заседании 33 члена НТС из общего числа 40 членов НТС.

НТС ЛФВЭ заслушал отчет и рассмотрел предложение о продлении проекта **Нуклотрон-NICA** (02-1-1065-1-2011/2024) темы (02-1-1065-2007/2026) «Комплекс NICA: создание комплекса ускорителей, коллайдера и экспериментальных установок на встречных и выведенных пучках ионов для изучения плотной барионной материи, спиновой структуры нуклонов и легких ядер, проведения прикладных и инновационных работ». НТС решил одобрить отчет и рекомендовать ПКК по физике частиц продлить проект до конца 2027 года.

Рецензенты: Б.Ю.Шарков, Г.Д.Ширков

Председатель НТС ЛФВЭ Е.А.Строковский

Ученый секретарь НТС ЛФВЭ С.П.Мерц

ABSTRACT OF THE MINUTES
OF THE APRIL 09, 2024
VBLHEP STC MEETING

33 STC members were present at the meeting out of a total of 40 STC members.

VBLHEP STC heard the report and considered the proposal on continuation of the **Nuclotron-NICA** (02-1-1065-1-2011/2024) project within the framework of theme (02-1-1065-2007/2026) "NICA Complex: Design and Construction of the Complex of Accelerators, Collider and Physics Experimental Facilities at Extracted and Colliding Ion Beams Aimed as Studying Dense Baryonic Matter and Spin Structure of Nucleons and Light Ions, and at Carrying out Applied and Innovation Projects". STC decided to endorse the report and to recommend that PAC for Particle Physics support continuation of the project until the end of 2027.

Referees: B.Yu.Sharkov, G.D.Shirkov

VBLHEP STC Chairman E.A.Strokovsky

VBLHEP STC Scientific Secretary S.P.Merts