Annex 3.

Form of opening (renewal) for Project / Sub-project of LRIP

APPROVED

JINR DIRECTOR

____________/__________________

"____" ____________________ 202 г.

PROJECT PROPOSAL FORM

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 (for extended projects): 04-2-1126-2015.

1.2 Project/LRIP subproject code (for extended projects) :04-2-1126-2015

1.3 Laboratory : Dzhelepov Laboratory of Nuclear Problems

1.4 Scientific field : Accelerators, detectors, R&D, applied research.

1.5 Title of the project/LRIP subproject: Design and development of a test zone for methodical studies of detectors at a linear electron accelerator in the DLNP.

1.6 Project/LRIP subproject leader(s) : M.I. Gostkin

1.7 Project/LRIP subproject deputy leader(s) (scientific supervisor(s)) : Abdelshakur El Said Mohammed Abu Elazm

2. Scientific case and project organization

2.1 Annotation:

Scientific and methodological studies of elementary particle detectors are a necessary condition for the progress of nuclear physics and high energy physics. The preparation of experiments at future accelerators requires the creation of new types of detectors capable of coping with large loads and providing the required accuracy and reliability of particle detection. The development of new detectors is also important for applied research based on the use of synchrotron radiation sources and intense X-ray facilities. In particular, the creation of new SR sources and super-powerful lasers in the JINR Member States leads to the creation of experimental stations based on detectors with high spatial and energy resolution. The ability to test detector prototypes on test beams plays a decisive role in scientific and methodological research. The lack of facilities with test electron beams at JINR significantly slows down progress in the creation of new types of electromagnetic calorimeters and coordinate detectors for future MPD and SPD experiments at the NICA collider, photon imaging detectors, radiation-resistant detectors and dosimetric instruments. The purpose of the presented project is to create an infrastructure based on the linear electron accelerator LINAC-200 for methodical research on electron beams with an energy of 20 MeV and 200 MeV. It is planned to use a test area based on LINAC-200 for conducting experiments on the study of photonuclear reactions, for applied research (radiation materials science, radiation genetics, etc.).

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

Aim: Design and development of the test zone infrastructure based on the LINAC-200 accelerator of test electron beams with energies up to 220 MeV to study the properties of elementary particle detectors for use by JINR groups and institutes of the JINR Member States, as well as for the external AMBER experiment at SPS CERN.

Scientific and methodological research on the creation of new types of detectors is a necessary condition for the further development of the experimental physics of the atomic nucleus and elementary particles. In particular, the preparation of experiments on new generation accelerators (ILC, CLIC, CEPC, HL-LHC) requires the development of new types of detectors capable of operating under high load conditions and at the same time providing the required speed, accuracy, and registration reliability [1-4]. In contrast to experiments at the LEP, the Tevatron, and the LHC, radiation resistance often comes first among the requirements, which is due both to the long operating time of the facilities under design and to the much higher loading compared to existing accelerator complexes due to high beam energy and luminosity of future accelerators.

Obviously, the development of new detectors is not limited to future collider experiments. Examples include experiments on the search for a neutrinoless muon-to-electron conversion, in which an extremely weak signal from electrons with a certain energy is required [5,6], as well as new-generation neutrino experiments, for which detectors with a high temporal resolution are being developed, capable of significantly to suppress background events by highlighting the direction of neutrino motion by separating Cherenkov light and photons from scintillation [7]. When testing detectors of this kind, the high intensity of the beam of existing accelerators, which leads to superposition of signals from many accelerated particles, presents a difficulty. To eliminate this problem, it is important to be able to obtain beams of accelerated particles with a low intensity (several tens or hundreds of electrons per second), which will make it possible to record the detector's response to a single incident particle.

The creation of new types of elementary particle detectors is important not only for high energy physics. The future of such sciences as biology, materials science and medicine today is closely connected with research using synchrotron, X-ray radiation sources and other nuclear physics methods. In the next decade, it is expected to launch new synchrotron sources and super-powerful pulsed lasers being created in JINR member states.

When studying the characteristics of detector prototypes in the course of scientific and methodological research, as well as during quality control during small-scale production, sources of elementary particles are certainly used. The most accessible and widespread are cosmic rays and radionuclide sources, however, the use of charged particle beams at the accelerator has a number of invaluable advantages, such as high energy and density of particle flux, the possibility of their reliable identification, the ability to control particle energy, time and coordinate binding. Some characteristics of detectors are simply impossible to determine without using particle beams from accelerators. However, at present, the capabilities of test particle beams in the DLNP and in JINR as a whole are extremely limited. The production of particles with an energy of 100 MeV and higher is possible only on a nuclotron, while only beams of protons and heavy ions are available. There is no source of high energy and good quality electrons in JINR. Geographically, the closest source of electrons of this kind is the synchrotron S-25P "Pakhra" LPI with an energy of 1 GeV, launched in 1974, which does not have equipped test beams.

The technical characteristics of the LINAC-200 accelerator, created at JINR, make it possible to create on its basis a developed system of test beams for scientific and methodological research of detectors in the interests of nuclear power plants, as well as other laboratories and member states of the Institute.

Available test electron beams.
Currently, there are about a dozen accelerator centers in the world where measurements with test electron beams are possible (see the table). However, working on test beams in international centers entails costs for transportation and maintenance of equipment, as well as delays, since shifts on test beams are usually distributed for years ahead. Currently, some of the international accelerator centers are not available to JINR employees (for example, DESY-II (Germany)).

Science Center	Year of construction of accelerator/beams	Particle type	Energy range [MeV]	dP/P [%]	The number of equipped lines
BTF (Frascati, Italy)	1997/2003	$e^{\pm}$	25-750	1	1
ELPH (Tohoku, Japan)	1997/2006	$e^{\pm}$	< 850	1	1
Bepc-II (IHEP, China, Beijing)	2008	e^{-} $e^{\pm}$ (secondary)	1100 - 1500 400 - 1200	1	3
FTBL (KEK, Japan)	1998/2007	e^{-}	500-3400	0,4	1
DESY-II (Germany)		e^{-}	1000-6000	1	3
CERN PS (Switzerland)	1960	e , hadrons, μ	$(1\text{-}15)*10^3$		4
CERN SPS (Switzerland)	1976	e , hadrons, μ	$(10\text{-}400)*10^3$		4
FTBF (FNAL, USA)	1999	e^{-}, π^{-} , μ	$(1\text{-}66)*10^3$		1
SLAC (USA)	1999	e^{-} e, hadrons, (secondary)	$13,6*10^3$ $(0,1\text{-}13,6)*10^3$	0,1-1,3	1
IHEP (Protvino, RF)	1967	e, hadrons, μ	$(1\text{-}45)*10^3$		4
BINP (Novosibirsk, RF)	1994/2012	e^{-}	100-3500	1,8-2	1
LPI (Troitsk, RF)	1974	e^{-}	300-1300		0

Yerevan Physics Institute (Armenia)	1967	e^-	75 6000		0
LINAC-200 (JINR)	*1975/2023*	*e^-*	*10 - 200*	*1*	*2*

Channels for the output of an electron beam at the LINAC-200 accelerator.

At present, there are two channels for extracting the electron beam from the LINAC-200 accelerator. The first channel allows measurements with a test electron beam with an energy of 10-25 MeV. The second is 40-200 MeV.

The energy spread of the beam does not exceed 1%. It is possible to focus a beam with a focal spot size of less than 1 mm, as well as the possibility of defocusing to ensure uniform illumination in an area measuring 20 cm x 20 cm. The beam intensity varies in the range from units to 10^{13} e-/s and changes by no more than 5% when taking measurements.

Each beam extraction channel includes a rotating magnet, quadrupole lenses for beam focusing, horizontal and vertical collimators, and a vacuum path for transporting the beam and extracting it into the atmosphere.

Each test beam must be equipped with equipment for measuring and monitoring the characteristics of the beam (energy, coordinates and direction, intensity). For this, BGO-based calorimeters, plastic scintillators, coordinate hodoscopes and beam profiling detectors, wire chambers, Faraday cups, ionization chambers and induction sensors will be used. Test beams must have the necessary set of standard fixtures for irradiating detectors, a system for positioning the samples under study in the beam, a set of collimators to form the required geometric parameters of the extracted electron beam, and the necessary local protection to reduce the radiation load and improve the background conditions during measurements.

An important task in creating test beam extraction channels is a systematic study of the characteristics of the extracted electron beam and mathematical modeling to optimize the measurement conditions.

Equipment of the test area.

1. Moving detectors.

The beam extraction channels are equipped with devices that allow moving the detectors under study, irradiated samples, and equipment weighing up to 100 kg in horizontal and vertical planes located on them. The horizontal movement node is LSDP-500FG. The vertical movement unit LSS-XW-400-400A consists of a system of vertical guides, a helical transmission, a motor gearbox and a stepper motor. It has a range of movements of 400 mm and a table for mounting 400x400 mm. Overall dimensions — 500x400x322 mm3, Linearity – 150 microns.

2. Remote visual monitoring - available via video cameras.

3. High-speed multiwire gas chambers (beam monitor).

Thin-gap high-speed coordinate proportional cambers [8] will be used to control the beam profile and intensity, as well as coordinate detectors for reconstructing the electron track of the LINAC-200 accelerator. The high voltage operating plateau is 1600 V, which allows operate in one of four modes: proportional, limited proportionality, plasma and self-extinguishing streamer.

Geometric characteristics of camber:

Sensitive area:	115 x 115 mm^2
Number of anode wires:	128

Pitch of anode wires:	0.9 mm
Distance anode-cathode:	1.3 mm
External chamber size:	236 x 236 mm^2
Chamber thickness:	37 mm

Counting rate for stretched beam:	5 x 10^7 cm^{-2}
Time resolution (jitter):	4.5 x 10^{-9} s

Front-end electronics: (prototype)

Basic electronics board: MT-48A-OKA-2 (analogue) and MT-48D-OKA-2 (digital)

Number of amplifier-shaper channels:	48
Number of time measurement channels:	49
Time measurement range:	up to ~16 ms
Time resolution:	1 ns
Buffer size:	1024 of 32-bit words
Registration dead time of channel:	~1000 ns
Single channel processing time:	232 ns
Power supply and current consumption:	+5 V - 2.1 A; -5V - 0.3A
Amplifier-shaper integrated circuit (ASIC):	OKA-2BK (8 channels)
Number of ASICs per board:	6 pcs

OKA-2BK ASIC parameters:

Number of channels:	8
Channel structure:	CSA+Shaper+BLR+Discriminator+MS+LVDS
Input resistance, Ohm:	60
Gain, mV/fC:	50÷80
Peaking time, ns:	10÷12
Base signal width at the output, ns:	26
ENC (r.m.s.), fC:	650+40e/pF
Threshold input:	common
Minimum threshold, fC:	3
Threshold adjustment range, fC:	3÷15
Threshold spread (sigma), fC:	1
Output signals:	LVDS
Output signal duration, ns:	150
Output signal delay, ns:	11
Channel-to-channel crosstalk, %:	0.5
Test input:	common
Internal test capacity, pF:	0.2

It is planned to work with ready-to-use gas mixtures.

4. Detector-profilometer of the simplest design:
it works on the coincidence of signals from 2 counters (HAMAMATSU H10720-20) with scintillating strips 2x2x110 mm

5. To determine the position of the beam, it is possible to use phosphor screens, radiochromic film. A system of three or five ionization chambers is also used, which is installed on the device for movement and allows for high accuracy control of the introduction of the irradiated object into the center of the electron beam or braking radiation. It is planned to use the Tetra m device to measure currents from ionization chambers. [9]

6. Measurement of energy.

Energy measurement and calibration of the output channel are a necessary step in conducting radiation tests. The standard method for determining the beam energy is to use a dipole magnet with a known magnetic field strength to output the beam, but in this case such measurements were technically extremely difficult, since they required disassembly of the channel. Therefore, an alternative new method of measuring the energy of an electron beam was used, developed by physicists of the JINR Nuclear Reactions Laboratory. The method [10] is based on measuring the ratio of saturation activities of several photonuclear reaction products obtained as a result of activation of indium foils by photons of the braking radiation of an electron beam accelerated on the MT-25 microtron. The physical feature of microtrons is that the electron beams accelerated with their help have high monoenergetics and known energy. The scintillation detectors from LaBr, BGO plastic scintillator in the electron beam LINAC-200 were calibrated and the energy spectra of the output electron beam were accurately measured by these detectors in the range up to 25 MeV. [11]

To measure the energy of the beams of the withdrawn electrons after passing collimators, filters, etc. It is proposed to use detectors based on plastic scintillators to determine background conditions. For example, a detector with a plastic scintillator is available

(made in DLNP, D=100mm, L=400mm), HAMAMATSU R6091.

It is also supposed to use detectors with BGO scintillators-a pyramid with a height of 57 mm.

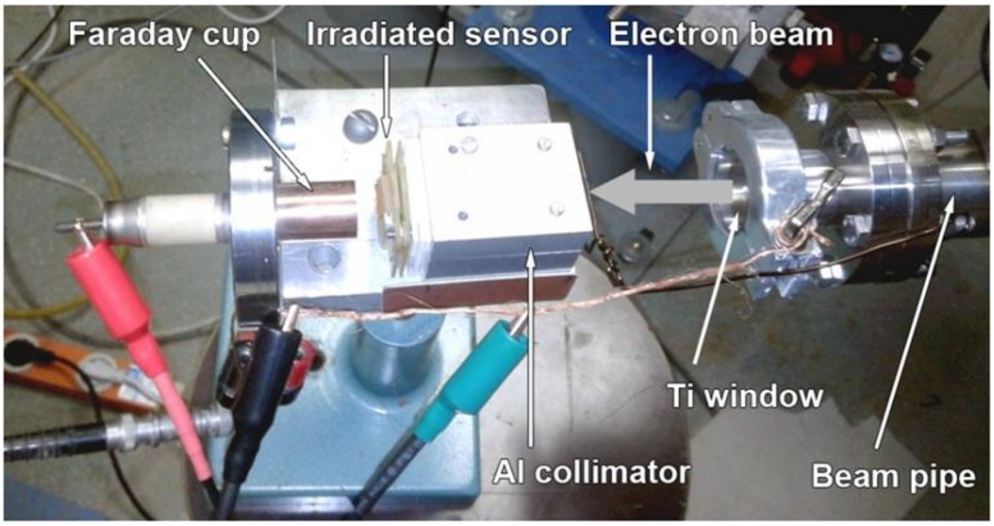
Equipment for measuring beam characteristics.

1. Keithley(digital electrometer) Model 6517B
2. Digital 2-channel oscilloscope.
3. The device for digitizing DRS-4 signals.

The DRS-4 digital oscilloscope is designed to digitize signals from PMT or other detectors, has the ability to record and plot spectra. DRS-4 has 4 input channels with an analog bandwidth of 350 MHz, allows digitizing signals at a speed of up to 5 = 109 samples per second. The trigger can be external (TTL signal), or set by the level of any input channel, or a combination of channels. The amplitude of the digitized signals in DRS-4 is limited to the level of 1 V, if necessary, to reduce the amplitude of the signal below 1 V, it is possible to use attenuators.

4. 2-channel power supply with output voltage (+/-) 1 to 3 kV
5. 8-channel power supply with output voltage (+/-) 1 to 4 kV

The set-up was assembled on the 20 MeV channel for irradiation of detectors and dose control.



Measuring the charge in the Faraday cylinder allows you to estimate the flow of electrons and calculate the absorbed dose. To do this, the Keithley 6517B meter is used, turned on in charge measurement mode. Since there is a sufficiently high level of radiation in the accelerator hall when the accelerator is operating, a special program was written for remote control and automatic data collection for the Keithley device in the LabVIEW development environment.

In addition to the conclusions of the electron beam at 20 and 200 MeV, an integral part of the test zone is the control panel, in which the equipment for controlling and monitoring the parameters of experimental equipment is located.
In the control room there are high-voltage power supplies of experimental equipment, computers for control and data set. The communication of the remote control with the beam terminals is carried out using specially laid cables and the Internet.
The test area also includes the room 112b of the housing 118 for measuring the spectra of irradiated samples, in which a gamma spectrometer is located, the basis of which is the HPGe detector Ortec GMX20-70-CW. With energy resolution (FWHM) for 1.33 MeV (Co-60): 1.85 keV
The detector is located in a vertical cryostat with liquid nitrogen.
A data set system with spectrometric electronics in the NIM standard.
The detector is surrounded by a partial passive protection made of lead.
Storage of irradiated samples in a special safe.
The maintenance of this spectrometer is carried out by the DLNP under the leadership of E.A. Yakushev.

It is planned to carry out scientific and methodological work on the creation of elementary particle detectors for various experiments in the equipped test area. For example:
1. Investigation of silicon pixel detectors for the vertex tracker of MPD and SPD experiments.
2. Calibration of electromagnetic calorimeter modules for the SPD experiment.
3. Investigation of the characteristics of detectors for the SPD installation straw tracker.
4. Investigation of the characteristics (efficiency, spatial resolution, maximum load) of bulk Micromegas gas detectors for SPD and AMBER experiments.
5. Calibration of detectors for the COMET experiment on low-intensity electron beams with energy up to 100 MeV.
6. Applied tasks (radiation materials science, radiation genetics).
7. Calibration of dosimetric devices in the interests of "SNIIP".
8. Conducting experiments to study photonuclear reactions

Expected results:
As a result of the implementation of the project, an equipped test zone will appear at the LINAC200 accelerator of DLNP JINR for carrying out scientific-methodical and scientific-experimental work by JINR groups and institutes of the JINR Member States.

Implementation risks - insufficient funding, logistical difficulties in acquiring materials and equipment for the development of the test area.

References
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11. Beam energy measurement on LINAC-200 accelerator and energy calibration of scintillation detectors by electrons in range from 1 MeV to 25 MeV / M. Krmar, Y. Teterev, A.G. Belov, S. Mitrofanov, S. Abou El-Azm, M. Gostkin, V. Kobets, U. Kruchonak, A. Nozdrin, S. Porokhovoy, M. Demichev // Nuclear Inst. and Methods in Physics Research – 2019 – A.935 – p.83-88 – ISSN 0168-9002

2.3 Estimated completion date: 2028

2.4 Participating JINR laboratories:

Dzhelepov Laboratory of Nuclear Problems
Veksler and Baldin Laboratory of High Energy Physics
Flerov Laboratory of Nuclear Reactions

2.4.1 MICC resource requirements

Computing resources	Distribution by year				
	1st year	2nd year	3rd year	4th year	5th year
Data storage (TB) - EOS - Tapes					
Tier 1 (CPU core hours)					
Tier 2 (CPU core hours)					
SC Govorun (CPU core hours) - CPU - GPU					
Clouds (CPU cores)					

2.5. Participating countries, scientific and educational organizations

Organization	Country	City	Participants	Type of agreement
University of Novi Sad, Serbia	Serbia	Novi Sad	M.Krmar	

2.6. Key partners *(those collaborators whose financial, infrastructural participation is substantial for the implementation of the research program. An example is JINR's participation in the LHC experiments at CERN).*

3. Manpower
3.1. Manpower needs in the first year of implementation

№№ n/a	Category of personnel	JINR staff, amount of FTE	JINR Associated Personnel, amount of FTE
1.	research scientists	4.9	
2.	engineers	2.2	
3.	specialists		
4.	office workers		
5.	technicians		
	Total:	**7.1**	

3.2. Available manpower
3.2.1. JINR staff

No.	Category of personnel	Full name	Division	Position
1.	research scientists	M.I. Gostkin	DLNP	head of the sector
2	research scientists	Abdelshakur El Said Mohammed Abu Elazm	DLNP	senior researcher
3	research scientists	A.S. Zhemchugov	DLNP	deputy head of department
4	research scientists	U. Kruchonak	DLNP	senior researcher
5	research scientists	A. Nozdrin	DLNP	senior researcher
6	research scientists	M. Demichev	DLNP	research associate
7	research scientists	V. Kobets	VBHEP	head of the sector
8	research scientists	S. Mitrofanov	FLNR	Head of the group
9	research scientists	Yu. Teterev	FLNR	senior researcher
10.	engineers	S. Porokhovoy	DLNP	Lead Engineer
11	engineers	D. Kharchenko	DLNP	senior engineer
12	engineers	D. Demin	DLNP	chief set-up engineer

3.2.2. JINR associated personnel

No.	Category of personnel	Partner organization	Amount of FTE
1.	research scientists		
2.	engineers		
3.	specialists		
4.	technicians		
	Total:		

4. Financing
4.1 Total estimated cost of the project/LRIP subproject 1075 thousand US dollars
The total cost estimate of the project (for the whole period, excluding salary).
The details are given in a separate table below.

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

Project (LRIP subproject) Leader __________/___________/

Date of submission of the project (LRIP subproject) to the Chief Scientific Secretary: _________
Date of decision of the laboratory's STC: ___March 30, 2023__ document number: __2023-5__

Year of the project (LRIP subproject) start: ________________

(for extended projects) – Project start year: _______

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	4th year	5th year
		International cooperation		15	15	15	15	15
		Materials		70	70	70	70	70
		Equipment, Third-party company services		130	130	130	130	130
		Commissioning						
		R&D contracts with other research organizations						
		Software purchasing						
		Design/construction						
		Service costs (*planned in case of direct project affiliation)*						
Resources required	**Standard hours**	Resources						
		– the amount of FTE,						
		– accelerator/installation,						
		– reactor,…						
Sources of funding	**JINR Budget**	JINR budget *(budget items)*	1075	215	215	215	215	215
	Extra fudning (supplementary estimates)	Contributions by partners Funds under contracts with customers Other sources of funding						

Project (LRIP subproject) Leader__________/_________________/

Laboratory Economist __________/_________________/

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

JINR VICE-DIRECTOR	SIGNATURE	NAME	DATE
CHIEF SCIENTIFIC SECRETARY	SIGNATURE	NAME	DATE
CHIEF ENGINEER	SIGNATURE	NAME	DATE
LABORATORY DIRECTOR	SIGNATURE	NAME	DATE
CHIEF LABORATORY ENGINEER	SIGNATURE	NAME	DATE
LABORATORY SCIENTIFIC SECRETARY THEME / LRIP LEADER	SIGNATURE	NAME	DATE
PROJECT / LRIP SUBPROJECT LEADER	SIGNATURE	NAME	DATE

APPROVED BY THE PAC	SIGNATURE	NAME	DATE