In total the completed form should not exceed 20 pages (together with tables).

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) - 02-1-1086-2009/2023 Strangeness in Hadronic Matter and Study of Inelastic Reactions Near Kinematical Borders

1.2 Project/LRIP subproject code (for extended projects)

1.3 Laboratory VBLHEP

1.4 Scientific field Particle physics and relativistic nuclear physics

1.5 Title of the project/LRIP subproject HyperNIS+SRC

1.6 Project/LRIP subproject leader(s) D.O. Krivenkov, J. Lukstins

1.7 Project/LRIP subproject deputy leader(s) (scientific supervisor(s)) M.A.Patsyuk

2 Scientific case and project organization

2.1 Annotation

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

The study of properties of the lightest hypernuclei is actual, has high significance and the Nuclotron beam is suitable place to investigate these tasks. The study of properties of light neutron-rich hypernuclei is of great interest, first of all, to clarify the theory of the intranuclear nucleon-nucleon interactions: the neutron halo, ΛN interaction including ΛN – ΣN conversion and the spin-dependent ΛN interaction etc. The special interest to this investigation is because of absence of reliable data on $^{6}_{\Lambda}H$ properties and theoretical predictions that are strongly depend on model and controversial. Simultaneously, the lifetimes and production cross sections of $^{4}_{\Lambda}H$ and $^{3}_{\Lambda}H$ will be studied in the same experiment. The measurements can be used as “reference points” to confirm the production and decay of $^{6}_{\Lambda}H$**.** In 2025 the study of poorly investigated $^{6}_{\Lambda}He$ has to be made including measurements of the lifetime and the production cross section. At least 500 events of $^{6}_{\Lambda}He$ production have to be detected. In 2025-2026 we are planning the search of $^{8}_{\Lambda}H$ hypernucleus, the study of non-mesonic decay of medium hypernuclei $^{10}_{\Lambda}Be$ and $^{10}_{\Lambda}B$, and tests for the measurement of Coulomb dissociation of $^{3}_{\Lambda}H$ which requires high statistics due to rare events of production and decay of hypernuclei $^{10}{}_{\Lambda}Be$ and $^{10}{}_{\Lambda}B$. Fortunately, this task can be simultaneously solved with the data collection for the SRC experiment.

The properties of nuclei are defined by interaction of their constituents: nucleons on the level of lower resolution and quarks and gluons at high resolution. The relation between these two descriptions remains a challenge. Short-Range Correlated (SRC) pairs of nucleons, which are temporary fluctuations of strongly interacting nucleons at a distance of around nucleon radius and individual momenta larger than that of mean-field nucleons, are coupled to both nuclear scales. Electron scattering experiments have shown the far-reaching impacts SRCs have on the many-body systems, the nucleon-nucleon interaction, and nucleon substructure.

HyperNIS program is aimed at investigation of the role which strangeness plays in nuclei (open strangeness in hypernuclei) and in nucleon (correlated $\bar{s}s$ pair, i.e. hidden intrinsic strangeness). An evidence from Frascati for three $^{6}_{\Lambda}H$ hypernuclei was reported [1, 2]. In the concluding remarks at the closing of the 11th International Conference on Hypernuclei and Strange Particle Physics (held in 2012 in Barcelona) the first observation of $^{6}_{\Lambda}H$ was mentioned by T.Nagae [3] as one of the four main achievements in hypernuclear physics reached during the last years. On the other hand, the E10 collaboration at J-PARC experiment did not observe missing mass peak corresponding to $^{6}_{\Lambda}H$ production [4]. However, A.Gal at the Barcelona Conference discussion noted, that there will be low probability to see signal from $^{6}_{\Lambda}H$ at J-PARC experiment due to high transferred momentum and, consequently, high momentum and excitation of produced hypernuclei. Theoretical predictions are strongly model dependent and are controversial as well. For example, E.Hiyama and others have calculated [5] that $^{6}_{\Lambda}H$ is not stable nucleus and should decay into $^{4}_{\Lambda}H + n + n$ if one takes into account the parameters of ^{5}H resonance measured up to now. At the same time there are estimates [6] showing that the binding energy for $^{6}_{\Lambda}H$ should be about a few MeV. So, it is necessary to carry out an experiment what can test $^{6}_{\Lambda}H$ hypernucleus without doubt. At J-PARC the search for $^{6}_{\Lambda}H$ was continued as the phase-1 of the J-PARC E10 experiment what was performed at the J-PARC 50 GeV proton-synchrotron facility. However, the search for $^{6}_{\Lambda}H$ by the $^{6}Li(\pi^{-}, K^{+})$ reaction at the pion beam momentum of 1.2 GeV/c gave no events again.

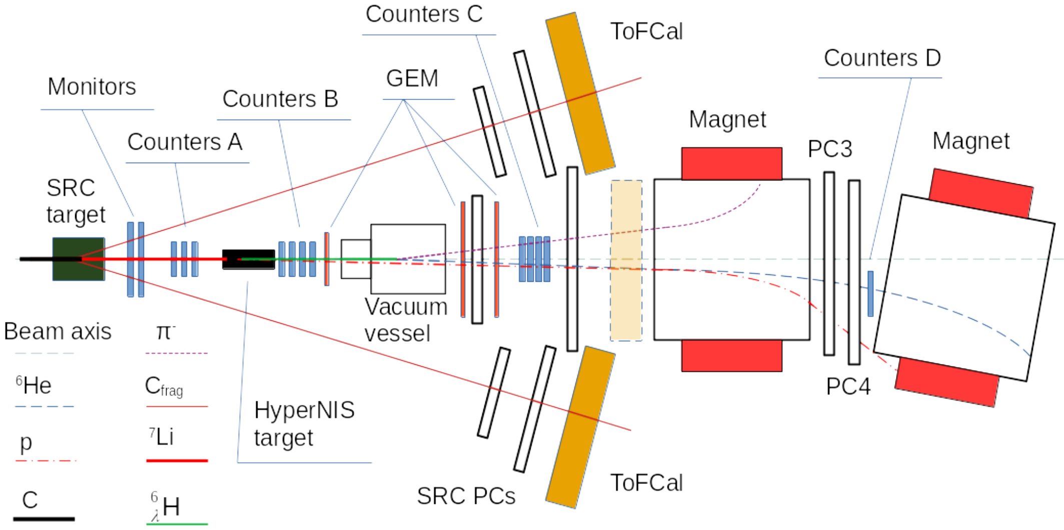
The HyperNIS installation includes 20 counters (16 scintillation and 4 Cherenkov), 10 proportional chambers, a time-of-flight system (RPC), a carbon target, a vacuum volume, and a magnet. GEM-detectors are paid and will be delivered and added to the setup. Second magnet and two arms of the spectrometer will be placed after SRC experiment integration. It's planned to use one of the arms as a ToF system for HyperNIS experiment. The principle of operation of the trigger used is based on the fact that upon decay of a hypernucleus with the emission of a π - meson, the nuclear charge increases by one, which makes it possible to reliably filter out the background from nuclear fragmentation, as well as to track the charge of the nucleus under study at all stages of the following reaction:

$$^{7}Li + {}^{12}C \rightarrow {}^{6}_{\Lambda}H + p_{frag} + K^{+}$$
$$\hookrightarrow {}^{6}He + \pi^{-}$$

A minimum of background events is also ensured by searching for the decay point of the hypernucleus in a vacuum, which eliminates fragmentation events that can simulate a useful signal.

Expected results upon completion of the theme stages or projects:

1. Experimental conclusion about the existence of the hypernucleus $^{6}_{\Lambda}H$.
2. New experimental data on the properties of the lightest hypernuclei and experimental verification of corresponding theoretical models for these hypernuclei.
3. New experimental data on the drip-line location for loosely bound light hypernuclei with high neutron excess, necessary for the development of the theory of neutron-rich hypernuclei and models of their production in non-central nucleus-nucleus interactions.
4. New experimental data on the production of strangeness and vector mesons (including those, containing strange quarks) by polarized photons (close to the relevant thresholds).



Scheme of the combined HyperNIS and SRC experimental setup

The optimal statistics for the goal of the experiment is 500 registered events of the production and decay of the hypernucleus $^{6}_{\Lambda}H$. At least 200 hours of beam time of the accelerator are needed.

The usage of ion beams opens completely new pathways in SRC research. Shooting a nuclear beam on a proton target makes possible to study properties of the nuclear fragments after quasi-elastic knockout of a single nucleon or SRC pair. The first SRC experiment at BM@N (2018) has shown that detection of an intact ^{11}B nucleus after interaction makes the scattering happen on a transparent carbon nucleus. Initial- and final-state interactions are suppressed for the set of quasi-elastic knockout events with ^{11}B in the final state. Also, 23 events of SRC-breakups showed agreement in SRC properties as known from electron beam experiments. The next stage of the SRC studies at BM@N (at 2022) included an improved setup with large hadron calorimeters for proton-pion separation, a better timing resolution with new scintillator trigger counters, and a laser system for simultaneous calibration of all scintillator detectors without the beam. The data analysis is ongoing. The emphasis for the next SRC experiment planned at the new HyperNIS location will be refined based on the analysis results. The main idea of this proposal is to show that the SRC setup can fit into the HyperNIS setup with minimal distraction. However, a larger band by the magnetic field is needed to obtain the required resolution. For that a second magnet needs to be installed

[1] M. Agnello et al. (FINUDA Collaboration), Phys. Rev. Lett. 108, 042501 (2012).
[2] E. Botta, Nucl. Phys. A 914, 119 (2013).
[3] T. Nagae, Nucl. Phys. A 914, 559 (2013).
[4] H. Sugimura et al. (J-PARC E10 Collaboration), Phys. Lett. B 729, 39 (2014).
[5] E. Hiyama et al., Nucl. Phys. A 908, 29 (2013).
[6] B. F. Gibson and I. R. Afnan, Nucl. Phys. A 914, 179 (2013); Few-Body Systems 55, 913 (2014).

2.3 Estimated completion date 2024-2028

2.4 Participating JINR laboratories VBLHEP, DLNP

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	0	0	0	0	0
Tier 1 (CPU core hours)	0	0	0	0	0
Tier 2 (CPU core hours)	0	0	0	0	0
SC Govorun (CPU core hours) - CPU - GPU	0	0	0	0	0
Clouds (CPU cores)	0	0	0	0	0

2.5. Participating countries, scientific and educational organizations

Organization	Country	City	Participants	Type of agreement
TAU	Israel	Tel Aviv	Kalbow J.	
TAU	Israel	Tel Aviv	Johansson G.	
MIT	USA	Kembrige	Hen O.	
RSNP	Japan	Osaka	Nakano T.	
RSNP	Japan	Osaka	Tokiyasu A.	
CTU	Czech Republic	Prague	Pospishil S.	

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	10,86	
2.	engineers	3,75	
3.	specialists		
4.	office workers		
5.	technicians		
	Total:	**14,6**	

3.2. Available manpower

3.2.1. JINR staff

No.	Category of personnel	Full name	Division	Position	Amount of FTE
1.	research scientists	Aksinenko V.D.	VBLHEP		0.77
		Atovullaev T.	VBLHEP		1
		Averyanov A.V.	VBLHEP		0.89
		Fechtchenko A.A.	VBLHEP		0.69
		Gertsenberger S.V.	VBLHEP		0.91
		Korotkova A.M.	VBLHEP		0.94
		Krivenkov D.O.	VBLHEP		0.7
		Lukstins J.	VBLHEP		0.45
		Nepochatykh S.M.	VBLHEP		1
		Patsyuk M.A.	VBLHEP		1
		Hvorostukhin A.S	VBLHEP		1
		Tereschenko V.V.	DLNP		0.2
2.	engineers	Atovullaeva A.	VBLHEP		1
		Okhrimenko O.V.	VBLHEP		1
		Parfenova N.G.	VBLHEP		0.5
		Plyashkevich S.N.	VBLHEP		1
		Salamatin A.V.	VBLHEP		0.5
		Bochkova A.G.	VBLHEP		0.5
3.	specialists				
4.	technicians				
	Total:				**13.1**

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

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: __________ document number: __________

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	75	15	15	15	15	15
		Materials	85	25	15	15	15	15
		Equipment, Third-party company services						
		Commissioning						
		R&D contracts with other research organizations						
		Software purchasing	10	2	2	2	2	2
		Design/construction						
		Service costs (*planned in case of direct project affiliation)*						
Resources required	**Standard hours**	Resources						
		– the amount of FTE,		15	15	15	15	15
		– accelerator/installation,		360	360	360	360	360
		– reactor,…						
Sources of funding	**JINR Budget**	JINR budget *(budget items)*						
	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