Annex 3.

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

APPROVED

JINR DIRECTOR

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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) - *the theme code includes the opening date, the closing date is not given, as it is determined by the completion dates of the projects in the topic.*

02-2-1099-2010/2026 Study of Neutrino Oscillations and Astrophysical Research

1.2 Project/LRIP subproject code (for extended projects)

02-2-1099-2-2015/2026

1.3 Laboratory
DLNP, BLTP, MLIT

1.4 Scientific field
Physics of elementary particles and relativistic nuclear physics

1.5 Title of the project/LRIP subproject
Studying neutrino properties in accelerator experiments

1.6 Project/LRIP subproject leader(s)
Liudmila Kolupaeva
Alexander Olshevskiy

1.7 Project/LRIP subproject deputy leader(s) (scientific supervisor(s))
Yuriy Gornushkin
Oleg Samoylov

2 Scientific case and project organization

2.1 Annotation

Neutrino physics is a rapidly growing field of high-energy physics with well-determined tasks and parameters to measure during upcoming years. This area has experienced an additional boost over the last 25 years due to the discovery of the neutrino oscillation phenomenon by the Super-Kamiokande and SNO experiments. Contemporary neutrino physics includes various searches beyond Standard Model phenomena as well as careful measurements of neutrino properties as intrinsic characteristics of this particle. This includes oscillation parameters, neutrino interactions, masses, etc.

Accelerator neutrino beam is an artificial good controlled source of these particles with well-studied systematic uncertainties and ability to adjust beam characteristics to increase sensitivity to target parameters. This is a valuable feature for both studying the particle properties and searching for new physics. The JINR physicists have long standing traditions for participation in the past and present accelerator based neutrino experiments and projects.

This proposal aims to gather JINR participation in accelerator neutrino experiments into one project. We expect to strengthen the JINR intellectual contribution into these experiments due to the synergy of sub-groups. This includes the present state-of-the-art: NOvA, T2K, DsTau and FASER experiments.

NOvA and T2K are the long-baseline accelerator neutrino experiments aiming to study the neutrino oscillations, namely the order of neutrino masses and the CP violation phase. Meanwhile, an additional goal is to enhance the precision of the already known parameters. Both experiments are expected to continue running until 2027 with final data analyses afterwards. In case of NOvA it is projected to have up to about 4σ sensitivity to the neutrino mass ordering and less than 2σ sensitivity to CP violation. In case of T2K the projected sensitivity to CP violation is up to 3σ.

The JINR group has been participating in the NOvA experiment since 2014, with a wide range of contributions that include experimental methods, computing, DDT and DAQ software, three-flavor oscillation analysis (the fits performed by JINR scientists became official NOvA results on measured oscillation parameters in 2018-2024), and other physics analyses and searches. Additionally, a NOvA Remote Operation Center (ROC) for data-taking control was built in Dubna as well as data storage and CPU cluster for data analysis. JINR scientists are involved in the management of NOvA occupying various positions such as exotic physics group convener, three-flavor oscillation analysis group convener, ROC-liaison, and DAQ, DDT, production, ROC experts.

The JINR group has been participating in the T2K experiment since 2020 with a primary contribution to the near detector upgrade, the axion-like particles' searches and systematic uncertainty evaluation based on data-quality checks for each data-taking period.

In spite of very high competition in oscillation physics, the common agreement is that all current and on-going experiments perfectly complement each other and provide not only the cross check, but being properly combined, introduce new features rather than a single result. In particular, operating at nearly the same oscillation phase, NOvA and T2K utilize significantly different baselines, which helps to solve parameter degeneracy. Thus ongoing NOvA and T2K acknowledge strength of each other and carry on fully shared joint analysis with JINR involved at present from the NOvA side.

Future prospects in this field are mainly associated with the future mega-science projects, DUNE and Hyper-Kamiokande. The main goal of these experiments is to finalize the measurement of the neutrino oscillation parameters. The JINR team has accumulated significant groundwork in these experiments by making a key contribution to the near detector complexes and performing physics analyses in NOvA and T2K that can be naturally extended to the next generation of long-baseline experiments. Methodical studies for the near detector complexes include R&D for light readout system in liquid argon and straw tubes for DUNE's near detectors NDLAr and SAND, respectively, as well as installation and studies of SuperFGD for the T2K near detector that will be inherited by Hyper-Kamiokande.

By now, an official participation of JINR is not confirmed neither in DUNE nor in HyperK projects and the present proposal is, therefore, concentrated on the existing JINR team engagements in

NOvA and T2K, which will allow the JINR team to keep on track of this physics and develop analyses methods and possible contribution to the future projects.

The FASER experiment is carrying out measurement of high energy neutrinos produced at LHC. The interaction cross-sections of all flavors in the energy range from several hundreds of GeV to a few TeV can be obtained - these are unique measurements never performed. It will be a valuable input for Monte-Carlo neutrino interaction generators and key parameters for high-energy neutrino measurements by large-scale Cherenkov observatories, such as Baikal-GVD, IceCube, and KM3NeT/ARCA. Also the use of this novel source of neutrino will have wide ranging implications for the study of neutrino properties, QCD, astroparticle physics, and searches for physics beyond the Standard Model.

Both FASER and NA65 (DsTau) will contribute to tau neutrino studies. In FASER it's expected to significantly increase the world's supply of reconstructed tau neutrinos and provide their studies at high energy. NA65 aims to study tau neutrino production in p-A interactions and to reduce the large systematic error in tau neutrino flux prediction in the neutrino beams.

The JINR group has taken part in NA65 since the beginning of the experiment, and contributed to all stages of the data collection. JINR is involved in the management of the DsTau collaboration (CB Chair) as well as data analysis (data simulation and distributed data mass processing responsibility). The group works on the development of new software for effective very high track density data analysis as well as the physics analysis.

The present project aims to continue JINR participation in accelerator neutrino experiments and maintain and strengthen existing activities and tasks in NOvA, T2K, FASER and NA65. These scientific objectives attract a lot of attention from students and young staff at JINR and provide a very good potential for growing and extending the JINR participation in this excellent physics with a good visibility.

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

Aim

The primary objective of the project is to measure the properties of neutrinos in accelerator experiments.

In the two decades since the discovery of neutrino oscillations, extensive studies of this phenomenon have been carried out using a plethora of unique experiments, which have provided remarkable and precise measurements of the parameters that define this process. Worth to note, that this process was first suggested in the 1950s by the world-renowned JINR scientist Bruno Pontecorvo.

Currently, the goal of oscillation experiments is to measure the neutrino oscillation parameters as fundamental characteristics of this Standard Model particle, with numerous applications in both theory and other neutrino experiments. Both the neutrino mass ordering and CP violation phase can be measured using accelerator neutrino beams, which also have the ability to switch between neutrino and antineutrino modes, a crucial capability for measuring CP and resolving degeneracies.

These days there are two running accelerator neutrino experiments in the world that aim to study three-flavor oscillations, NOvA[1] and T2K[2]. Both experiments use a narrow-band off-axis beam whose peak energy is near the first oscillation maximum. T2K uses a neutrino beam peaked at 0.6 GeV from the J-PARC facility in Tokai, Japan, and the 50-kton Super-Kamiokande water Cherenkov for its far detector located 295 km away. NOvA's beam peaked at 2 GeV is produced at Fermilab near Chicago, USA, and the 14-kton fully active tracking calorimeter far detector is located 810 km away in northern Minnesota. In case of both experiments the appearance of electron (anti)neutrinos and the disappearance of muon (anti)neutrinos in the muon (anti)neutrino-dominated beam is observed. By

1 Ayres D et al. (NOvA Collaboration), hep-ex/0503053.

2 Abe K et al. (T2K Collaboration), Nucl. Instrum. Meth. A **659,** 106 (2011).

measuring these neutrino oscillations along with their antineutrino counterparts, both NOvA and T2K are probing the neutrino mass ordering, the leptonic CP violation parameterized by the phase δ_{CP}, the larger neutrino mass splitting Δm^2_{32}, and the mixing angle θ_{23}. Combining the results with those from other ongoing and soon upcoming experiments can provide important insights into the values of yet unknown parameters. But the final answer will be most likely obtained by the next generation experiments, such as DUNE[3] and HyperK[4].

In addition to the primary objective, the NOvA and T2K projects have a wide variety of scientific goals. These include Beyond Standard Model searches and the study of free particle sources, such as supernova neutrinos, atmospheric neutrinos and muons, and the detection of magnetic monopoles and dark photons if they exist.

Until recently as accelerator neutrinos were considered only those produced with help of extracted proton beams. However, the proton colliders also copiously produce both neutrinos and antineutrinos of all flavors, and they do so in a range of very high energies where neutrino interactions have not yet been observed. In particular, the LHC is the highest energy particle collider built so far, and it is therefore also the source of the most energetic human-made neutrinos created in a controlled laboratory environment.

To detect and study the collider neutrinos as well as other weakly interacting particles in the far-forward region, the FASER (ForwArd Search ExpeRiment)[5] - a relatively small and inexpensive detector was installed at a prolongation of one of the proton beams 480 m away from the ATLAS interaction point in the TI12 service tunnel. The main goal of the experiment is to measure the CC interaction cross section for neutrinos of all flavors in the energy range from several hundreds of GeV to a few TeV. Also the use of this novel source of neutrino will have wide ranging implications for the study of neutrino properties, QCD, astroparticle physics, and searches for physics beyond the Standard Model[6].

The DsTau (NA65) experiment[7] at CERN was proposed to measure an inclusive differential cross-section of D_s production with a decay to tau lepton and tau neutrino in p-A interactions. The reaction is a main source of tau neutrinos in accelerator neutrino beams. Currently this cross section is poorly estimated, which leads to the large systematic error in tau neutrino flux prediction in the neutrino beams. This experiment will contribute to the reduction of corresponding systematics uncertainties in other experiments, including ongoing accelerator ones. The DsTau detector is also based on the nuclear emulsion technique, which provides excellent spatial resolution for detecting short-lived particles like charmed hadrons or tau lepton.

Relevance and scientific novelty

All properties that are expected to be measured within this project are intrinsic characteristics of neutrinos as Standard model particles. They are valuable for the theory as well as an input for other experiments with neutrinos including the ones aiming to the search for new physics.

The scientific reasons for performing studies on neutrino oscillations are manifold. One of the reasons is the significant role that the order of masses plays in modeling neutrino fluxes during supernova explosions[8]. Furthermore, this parameter is crucial for evaluating the prospects of a whole class of experiments in neutrino physics that aim to search for neutrinoless double beta decay[9] and is an input parameter for experiments on direct measurement of neutrino masses[10] and search for relic

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3 Abi B et al. (DUNE Collaboration), JINST 15 (2020) 08, T08008.

4 Abe K et al. (Hyper-Kamiokande Collaboration), 1805.04163 [physics.ins-det].

5 Ariga A et al., Phys. Rev.. D **99**, 095011 (2019).

6 J. L. Feng et al., J. Phys. G 50 (2023) no. 3,460 030501,

7 Aoki S et al., JHEP **01**, 013 (2020).

8 Scholberg K J J, Phys. G **45**, 014002 (2018).

9 Dolinski M J et al., Ann. Rev. Nucl. Part. Sci. **69**, 219 (2019).

10 Qian X et al., Prog. Part. Nucl. Phys. **83**, 1 (2015).

neutrinos[11]. The phase of CP violation in the lepton sector, δ_{CP}, also has one main application that cannot be overestimated - it is associated with checking the origin of the asymmetry between matter and antimatter in the Universe[12].

All the parameters of neutrino oscillations are fundamental characteristics of this particle and are essential for understanding the process of neutrino propagation, which influences any possible practical applications of these particles that involve their movement. Some of the applications of neutrino beams include monitoring the operation of nuclear reactors, tomography of the Earth, and space exploration using ultrahigh-energy neutrinos.

In the past two decades, significant progress has been made in neutrino oscillation physics but neutrino mass ordering and δ_{CP} still remain unmeasured. Current generation of accelerator neutrino experiments (T2K and NOvA) have made one of their primary goals to study these parameters. Before them these measurements were not carried out. Another type of neutrino experiment that can measure both δ_{CP} and neutrino mass ordering is atmospheric neutrino experiments, which use naturally produced neutrinos and antineutrinos via colliding of cosmic rays with the atmosphere. Currently, the main player in this field is the ongoing Super-Kamiokande[13] experiment. However, measurement of δ_{CP} with atmospheric neutrinos is complicated due to the difficulty in separating neutrino/antineutrino events. Nevertheless, NOvA, Super-Kamiokande, and T2K are the only current oscillation experiments reporting measurements of δ_{CP} and mass ordering.

In spite of the fact that T2K, Super-Kamiokande and NOvA will run a few more years it's clear from current sensitivity estimations that they will not make a measurement of neutrino mass ordering and δ_{CP} at a discovery level. Although there are some expectations about joint analyses. Recently two such joint analyses were announced. Super-Kamiokande and T2K[14] as well as NOvA and T2K[15] presented in 2023-2024 their first combined results in full-fledged joint fit. That was the first such result in neutrino physics. It's worth to note that HEP experiments on LEP and LHC colliders have been performing similar analyses for decades.

There are several experiments in preparation that have the goal of finalizing δ_{CP} and mass ordering measurement: IceCube's DeepCore[16], JUNO[17], ORCA[18]. There are also future long baseline accelerator experiments Hyper-Kamiokande and DUNE, that have a very similar setup. Their first results are expected to be announced closer to the end of decade. On the current landscape there are also several future projects with unclear status: PINGU[19], ICAL@INO[20], ESSνSB[21], Protvino-to-ORCA[22], SuperCHOOZ[23], second Far Detector tank in Korea[24] for Hyper-Kamiokande. In case of their approval most likely they'll start producing results in late 2030s. Thus in the upcoming years NOvA and T2K data will continue to provide valuable information on neutrino oscillation parameters.

Another intrinsic characteristic of these particles, neutrino charged current (CC) interaction cross section, has been measured in multiple experiments from low energies to ~300 GeV. On the other hand

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11 De Salas P F et al., Front. Astron. Space Sci. **5**, 36 (2018).

12 Pascoli S et al., Phys. Rev. D **75,** 083511 (2007); Branco G et al., Phys. Lett. B **645**, 432 (2007).

13 Fukuda Y et al. (Super-Kamiokande Collab) Phys. Rev. Lett. **81**, 1562 (1998).

14 Abe K et al. (T2K and Super-Kamiokande Collaborations), 2405.12488 [hep-ex].

15 Atkin E "Results from the T2K+NOvA Joint Analysis", KEK seminar, 2024; Vallari Z, "Results from a joint analysis of data from NOvA and T2K", FNAL seminar, 2024.

16 Ishihara A et al. (IceCube Collaboration), PoS ICRC2019, 1031 (2020).

17 Adam T et al. (JUNO Collaboration), 1508.07166 [physics.ins-det].

18 Adrian-Martinez S et al. (KM3Net Collaboration), J. Phys. G **43**, 084001 (2016).

19 Aartsen M et al. (IceCube Collaboration), J. Phys. G **44**, 054006 (2017).

20 Ahmed S et al. (ICAL Collaboration), Pramana **88**, 79 (2017).

21 Blennow M et al., Eur. Phys. J. C **80**, 190 (2020).

22 Akindinov A V et al. (P2O Proto-collaboration), Eur. Phys. J. C **79**, 758 (2019).

23 Cabrera A, "The SuperChooz experiment: Unveiling the opportunity", CERN seminar, 2022, https://indico.cern.ch/event/1215214/

24 Abe K et al. (Hyper-Kamiokande Collaboration), PTEP **2018** 6, 063C01 (2018).

neutrino telescopes like Baikal-GVD[25], IceCube[26], KM3NeT[27] detect neutrinos of much higher energies – several TeV and more. Moreover the cross section measurements in these experiments have relatively large statistical errors and may have unknown systematic deviation. The collider neutrinos have energy in the intermediate range, from several hundreds of GeV up to several TeV, hence can constrain astroparticle measurements. The number of such neutrinos produced at LHC interaction points is enormous. Proton-proton collisions typically lead to a large number of hadrons produced along the beam collision axis, which can inherit an O(1) fraction of the proton's momenta. The decay of those hadrons leads to a powerful stream of high-energy neutrinos, which are highly collimated around the beam collision axis.

In 2024 the FASER Collaboration has reported on detection of the muon and electron neutrinos from the collider for the first time and estimated the CC interaction cross section for them in the energy region from several hundreds of GeV to a few TeV completely unprobed so far[28] . Those results have been obtained after the analysis of a relatively small data sample corresponding to 9.5 fb^{-1} of integrated luminosity collected with the dedicated FASERν detector, a part of the setup dedicated for neutrino physics and based on nuclear emulsion technique. The LHC Run 3 continues, more data will be collected, its analysis is ongoing and significant improvement is expected after full data of the Run 3 (corresponding to ~250 fb^{-1}) processing will be completed. Besides detection of several thousands of electron and muon neutrinos this detector will accumulate about 20 ν_τ CC interactions. This will significantly increase the world's supply of reconstructed tau neutrinos and will allow them to be studied at much higher energies E_ν ~ TeV. Due to its high spatial resolution, the FASERν detector will be able to resolve the shape of each neutrino event, including, for example, the multiplicity and momentum distributions of charged particles. These event shapes will provide valuable input to tune MC tools used to simulate high-energy neutrino events, such as GENIE[29].

Aside from probing neutrino interactions, the neutrino measurements at FASERν can also be used to constrain neutrino production rates. Although the existing LHC detectors have great coverage of the central region, the production of particles in the very forward direction along the beam pipe is only poorly constrained. In this regime, the measurement of the neutrino flux and spectrum at FASERν will provide complementary constraints on neutrino production, which could help to validate and improve the underlying hadronic interactions models. Those models are used to simulate multi-parton interactions and underlying events at the LHC, and they are also used to simulate cosmic ray events. The measurement of forward neutrino production will also be a key input for high-energy neutrino measurements by large-scale Cherenkov observatories, such as Baikal-GVD, IceCube, and KM3NeT/ARCA. One of the main aims of these experiments is to search for high-energy astrophysical neutrinos. This is subject to atmospheric neutrino background with an important prompt component from the decays of heavy mesons. Such a component is expected to become dominant at the highest energies, but it has not yet been identified. A direct measurement of the currently poorly-constrained prompt flux by FASERν would provide important data for all current and future high-energy neutrino telescopes.

The NA65 (DsTau) experiment aims to measure tau neutrino production in p-A interactions at CERN-SPS. An accurate knowledge of tau neutrino flux in accelerator neutrino beams is essential for ongoing and future neutrino experiments like FASER, SND@LHC[30], SHiP[31] in which tau neutrinos interactions will be studied with relatively high statistics. The study of tau neutrino interactions is an important probe in constraining the models beyond the Standard Model. For example, the lepton flavor

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25 Avrorin A D et al., Nucl. Instrum. Meth. A **742**, 82 (2014).

26 Aarsten M et al., Nature **551**, 596 (2017).

27 Chiarusi T, Nucl. Instrum. Meth. A **952**, 161653 (2020).

28 Abraham R M et al., Phys. Rev. Lett. **133**, 021802 (2024).

29 Alvarez-Ruso L et al. (GENIE Collaboration), Eur. Phys. J. ST **230**, 4449 (2021).

30 Acampora G et al., JINST **19**, 05 (2024).

31 Ahdida C et al., Eur. Phys. J. C **82**, 5 (2022).

universality of the weak interaction can be tested in the neutrino sector as complementary to measurements in the LHCb[32] and Belle II[33] experiments where some deviation has been observed.

Methods and approaches

Primary tool for all experiments in this project, except FASER, is an accelerator neutrino beam that is produced with proton beam injection to the fixed target. In the case of NOvA and T2K experiments, the neutrino beam travels hundreds of kilometers to allow oscillations to happen and is detected with far detectors. FASER is the first experiment which uses high energy neutrinos from LHC for studying their properties.

NOvA

In the case of NOvA, the accelerator complex at Fermilab, inherited from Tevatron, is used to produce 120 GeV protons that are delivered to the carbon target. The neutrino beamline facility is inherited from NOvA's predecessor, the MINOS experiment. Magnetic horns, placed after the target, focus either positively or negatively charged mesons depending on the mode in which the experiment works (neutrino or antineutrino). Switching the horn current allows for changing the electric charge sign of the focused beam. These pions and kaons then produce neutrinos while traveling through the decay pipe. In the case of the neutrino mode (antineutrino mode), the beam has the following composition — 95% ν_μ, 4% $\bar{\nu}_\mu$, 1% $\nu_e + \bar{\nu}_e$ (93% $\bar{\nu}_\mu$, 6% ν_μ, 1% $\nu_e + \bar{\nu}_e$). The wrong sign background and the $\nu_e(\bar{\nu}_e)$ component mostly appear due to muon decays.

The accelerator complex at Fermilab is constantly being upgraded to produce more neutrinos. Thus, the designed power of the proton beam for NOvA was 700 kW, and recently, a 900 kW cable target and horns were installed. Currently the experiment works at 850 kW beam power on average. The recent record established by the FNAL accelerator in summer of 2024 was 1018 kW beam power. Accelerator neutrino experiments measure exposure in terms of protons delivered to the target (POT). NOvA's most up-to-date analysis was performed with 26.61 x 10^{20} POT (neutrino beam) and 12.5 x 10^{20} POT (antineutrino beam). It is expected to roughly double antineutrino beam exposure by the end of datataking.

Neutrinos travel through the Earth's crust to reach the Near Detector, which is located 1 km after the target to measure the initial neutrino flux. This is an important tool for controlling the initial beam composition, especially existing backgrounds and systematics. The Far Detector is placed 810 km away from the target and measures the neutrino flux after oscillations. Both NOvA detectors are placed off the beam axis at 14 mrad, which allows for obtaining a narrow energy peak at 2 GeV and suppressing high-energy tail backgrounds. The NOvA detectors are identical tracking calorimeters made of PVC cells filled with a liquid organic scintillator based on mineral oil with 5% pseudocumene. These cells are composed into planes, and planes with horizontal and vertical orientations alternate each other. The Far Detector (Near Detector) has dimensions of 15.4 m x 15.4 m x 60 m (4 m x 4 m x 16 m). Experiment setup is shown in Figure 1.

The detectors are optimal for measuring $\nu_e(\bar{\nu}_e)$ and $\nu_\mu(\bar{\nu}_\mu)$ via charged current interactions. Due to the identical detectors, systematic uncertainties corresponding to the neutrino interaction cross-sections and flux partially cancel each other. Data-driven predictions based on the extrapolation of the measured event rate in the Near Detector are used for fitting Far Detector data. NOvA developed two fitting approaches based on Frequentist and Bayesian hypothesis, and both showed similar performance.

JINR collaborators are working for many years in the three-flavor oscillation analysis group in NOvA with different activities depending on the group needs. Recent 2024 analysis of NOvA data

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[32] Aaij R et al., JHEP **08**, 055 (2017).

[33] Adachi I et al., Phys. Rev. Lett. **131**, 1801 (2023).

with increased statistics and improved analysis methods was performed with noticeable contribution of JINR physicists. Contribution for this round of analysis included neutrino energy estimation re-evaluation and data fitting as well as a cumulative contribution in other analysis areas over the last 8 years (development of selections, extrapolation procedure, systematics, fitting procedures, etc).

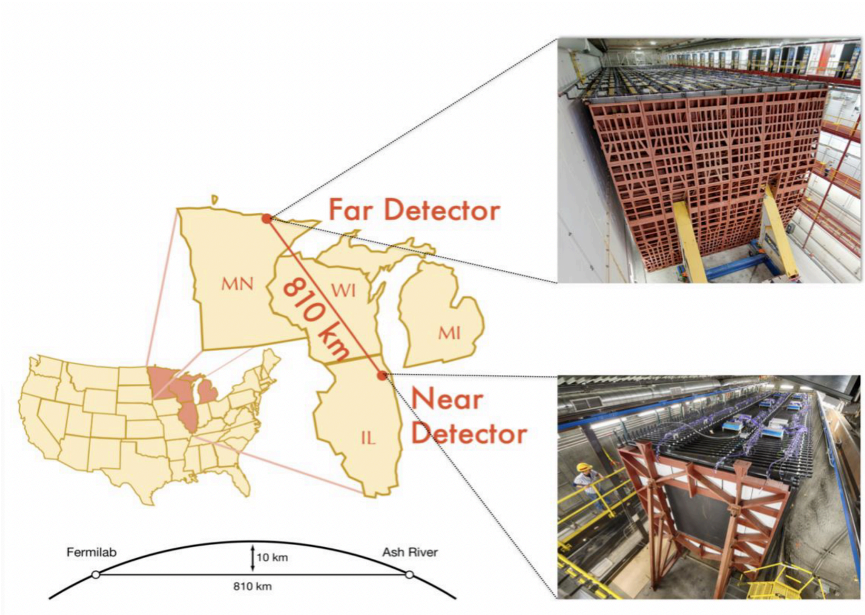

Figure 1. The NOvA experiment setup and detectors.

Another activity where JINR physicists are involved is joint analysis of NOvA and T2K data. Recently results of the first analysis were announced, and right now the group is finalizing the paper. JINR physicists were involved in development of this analysis as well as final fits. In the future, final joint analysis of NOvA and T2K data is planned. A few additional joint analyses are under consideration by collaborations. This can involve joint sterile neutrino searches, NSI, cross-section measurements and so on. JINR physicists plan to take part in these analyses.

The NOvA collaboration, with contributions from the JINR group, completed an in-depth analysis of neutrino interactions aimed at detecting supernova signals. This work focused on developing a comprehensive system to detect, select, and analyze neutrino interactions within the NOvA detectors in order to identify signals from core-collapse supernovae. The system was successfully implemented and deployed for NOvA detectors and is designed to support integration with the SuperNova Early Warning System (SNEWS) for combined analyses across multiple experiments. Andrey Sheshukov defended his PhD thesis on this work in 2024. Additionally, this analysis was extended to identify neutrino signals from the final stages of stellar evolution — presupernova neutrino signals — providing crucial insight into processes leading up to core-collapse events.

The NOvA experiment has made significant advances in the search for slow magnetic monopoles and in understanding detector response characteristics. The team, including JINR physicists, developed a high-efficiency detection system for slow monopoles on Earth using a highly segmented liquid scintillator detector, optimized in both low- and high-gain modes. The test stands were implemented to measure the response of NOvA's electronics and liquid scintillator, including charge and timing characteristics, Birks' coefficient, and the Cherenkov component in the light output. Simulations were conducted with these parameters to evaluate detector response to slow monopoles, including background contributions and signal optimization for maximum efficiency. The analysis is almost to the final stage.

Due to the surface location of the NOvA far detector, it can be used as a telescope for observing cosmic and atmospheric particles. This setup provides an excellent opportunity for detailed studies of atmospheric neutrino and muon fluxes, including investigations into seasonal variations, correlations with solar and weather events, geomagnetic effects, and high-energy muons and showers, among other physics. The Dubna group actively participates in and conducts several analyses in these areas, contributing valuable insights into particle behavior under various atmospheric conditions. Beyond this work, the Dubna team contributes to the search for exotic particles, aiding in the discovery of new phenomena and enhancing the broader scientific knowledge within the NOvA collaboration.

The JINR computer infrastructure on the basis of GRID and Cloud technologies was developed. It is efficiently used for the home-based running of jobs and is also a part of the NOvA distributed computing resources system for the use at peak loads (e.g., before conferences). Especially for the NOvA experiment 39 new servers were purchased and added to the JINR Cloud extending its resources by ~1000 CPU cores and ~6 TB RAM. These servers were used to host VMs of the new batch cluster and the OSG-site, allowing it to process jobs from both local JINR NOvA team and the NOvA jobs coming from the OSG, contributing directly to the NOvA collaboration. In this system every component of a Grid-site is virtualized, which is a first-time experience for the JINR Grid-sites and is an important step for further development of computing models at JINR. With the expansion of the virtual computing cluster, developing local data storage to retain copies of frequently requested experimental data became a high-priority task. Establishing such a storage system has proven essential for enhancing the efficiency of local data analysis. To build the storage backend, 17 storage servers were acquired and integrated into the cloud's Ceph storage system providing over 3.8 PB of disk space for storing experimental data.

Already in 2015, the first non-American remote operation center for the NOvA experiment (ROC-Dubna) was established at JINR by the Dubna team. The existence of ROC-Dubna allows physicists from JINR, as well as from INR and LPI (NOvA collaboration members), to control the datataking and monitor the experiment and the NuMI neutrino complex status. ROC-Dubna is a fully equipped center, furnished with the hardware and software required for DAQ, detector management, and neutrino beam monitoring. Real-time connection to the detector software is facilitated through remote VNC (Virtual Network Connection) sessions via ssh (secure shell) tunnels. Operations are supported on the Alma Linux, Ubuntu, and OSX operating systems. The ROC operation scripts are written in Python, and the FNAL Kerberos authentication system is used for security. Web applications connected to databases are used for beam monitoring, detector visual inspections (via video cameras), and recorded data quality checks. For audio and video communication Zoom platform and both landline and cellphones are utilized. The center can accommodate regular duty operators as well as experts for troubleshooting or developing new software. Additionally, ROC-Dubna can serve as a training facility for students and young scientists, as well as a demonstration space for teachers, school students, and the general public.

T2K

The T2K experiment (Figure 2) began collecting data four years earlier than NOvA, since 2010. The proton synchrotron of the J-PARC is used to form a neutrino/antineutrino beam for this experiment. In 2020, a record high beam power of 515 kW was achieved (the experiment facility operates stably at this value).

The T2K near detector complex, located at a distance of 280 m from the target, consists of the INGRID (Interactive Neutrino GRID) on-axis detector and the ND280 facility located at an angle of 2.5^{o} off-axis. INGRID is a sandwich structure assembled from cross-shaped modules. The modules consist of iron planes and a segmented scintillator. Neutrino events are identified by muon tracks, which set the beam direction and profile.

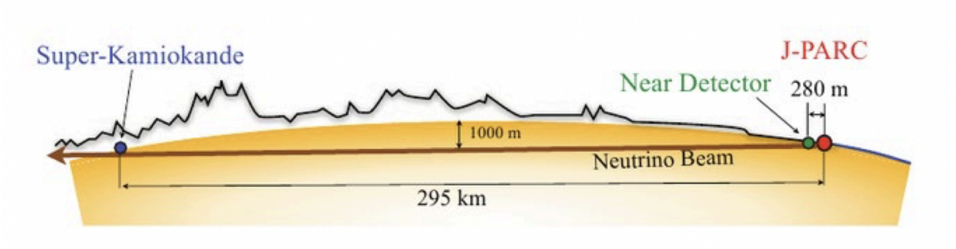

Figure 2. The T2K experiment setup

The detector complex, which is essential for oscillation physics, ND280, located in the same experimental hall but at an angle to the beam, consists of several parts (Figure 3):

- SuperFGD scintillation detector with two horizontal time-projection chambers and a time-of-flight detector around this new tracker;
- tracking detector based on Time-Projection Chambers;
- two highly segmented scintillation detectors, FGD (Fine Grained Detector);
- electromagnetic calorimeter, ECAL, supplementing the internal detectors for complete reconstruction of all events;
- SMRD (Side Muon Range Detector) for detecting muons with large angles of emission with respect to the beam direction, which also operates as a veto system for cosmic muons.

These devices are located inside the magnet of the former UA1 experiment.

JINR physicists were involved in recent installation and studies of the SuperFGD detector. This upgrade started the Phase-II of the T2K experiment with expected total systematic error decrease from 5±6% to 3±4%. This reduction is important for the T2K oscillation physics program and crucial for the future experiment Hyper-Kamiokande that will utilize the same near detector complex.

T2K's far detector is a Super-Kamiokande located at a distance of 295 km from J-PARC. Its Cherenkov detector, which is a cylinder 39 m in diameter and 42 m in height filled with 50 kt of pure water, consists of two parts: internal and external. Events from the internal detector (in which 40% of the surface are geometrically covered with photomultipliers) are used for the physics program. The external detector provides background protection and operates as a veto system for atmospheric muons. Super-Kamiokande can detect atmospheric, accelerator, and solar neutrinos, owing to which its science program is very rich.

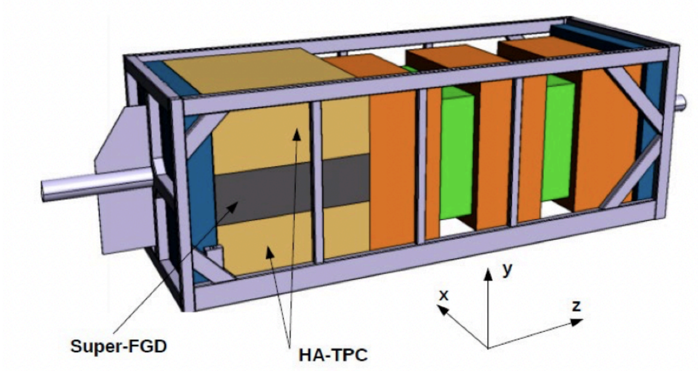

Figure 3. The model of the ND280 upgrade detector. In the upstream part there are two high angle TPCs (brown) with the scintillator detector Super-FGD (gray) installed between them. In the downstream part, the tracker system composed of three TPCs (orange) and the two FGDs (green) will remain unchanged. The TOF detectors are not shown in this plot. The beam travels along the z axis.

The JINR group is involved in the search for axion-like particles using data from the ND280 near detector. Axions and axion-like particles (ALPs) have been suggested in connection with the explanation of many mysteries of nature, such as the strong CP and the dark matter problems, and otherwise they are ubiquitous in string theory. ALPs at the MeV to GeV mass scales are of particular interest to beam dump and fixed target experiments and have been studied in the context of heavy axions, the parameter space of which goes beyond the traditional models of QCD axions. The JINR group plans to search for ALPs using data from the ND280 near detector and expect to obtain new constraints on the parameters of the ALP model.

JINR physicists continue working on systematic uncertainty evaluation based on data-quality checks for each data-taking period. These studies are taking into account detector-related changes over the time that are incorporated in Monte-Carlo predictions and can affect the results' robustness.

A new direction of the JINR group was begun by joining the ND280 Machine Learning group. This will enable the integration of advanced ML techniques to enhance data interpretation and explore innovative solutions for improving analysis accuracy.

JINR theorists plan to work on implementation in the T2K event analysis tools of several updated phenomenological schemes for calculating electromagnetic form factors of the nucleon, necessary for analysis of neutrino interactions in the T2K near detectors. It is expected to improve estimates of the impact of uncertainty in some of the most accurate current form-factor models on the prediction of neutrino event count rates[34].

It is also planned to investigate the potential of competing phenomenological models of neutrino-nucleus quasielastic scattering, for an accurate quantitative description of (anti)neutrino interactions with the INGRID and ND280 detector targets. In particular, the model of "running axial mass"[35] (sometimes called "Dubna model") will be tested. Expected results are the determination of refined relativistic Fermi-gas model parameters (Fermi momenta, binding energies, effective nucleon masses in nuclei) from a new global fit to modern electron-nucleus scattering data

Future prospects

These days there are two future long-baseline accelerator neutrino experiments with firm building timelines: DUNE will be NOvA's successor as the next flagship of Fermilab in neutrino physics, while Hyper-Kamiokande will inherit T2K's facilities and physics program. The JINR team has accumulated significant groundwork in these experiments by making a key contribution to the near detector complexes and performing physics analyses in NOvA and T2K that can be naturally extended to the next generation of long-baseline experiments. Although DUNE and HyperK are outside of the scope of this project we'd like to describe them briefly as well.

Compared to NOvA, the DUNE experiment will have several major differences. This experiment is expected to start data-taking in the late 2020s. The accelerator complex at Fermilab is currently being upgraded to provide a proton beam of ~1.2 MW for DUNE (Phase-I of experiment), with plans to upgrade the beam power to 2.1 MW after several years of running by replacing some subparts of the accelerator complex (Phase-II). Additionally, all components of the neutrino beamline (target, horns, decay pipe) will be different from NOvA, and neutrinos will travel 1300 km to the Far Detector complex. Far Detector will consist of four modules. Two TPC modules with dimensions of 19 m x 18 m x 66 m and a total of 17 kt of liquid argon (LArTPC) each will be installed during Phase-I. Two other modules will be installed for Phase-II. The Near Detector complex[36] is planned to consist of three detectors: NDLAr, which will also be a liquid argon TPC with 35 modules to maintain similarity with DUNE Far Detector modules with smaller size, another detector NDGAr that will measure charge of muons leaving NDLAr after neutrino interactions, consisting of a magnet and a gas argon TPC. These two detectors will be placed on a movable platform that will allow them to provide beam

[34] Kuzmin K S, Levashko N M, and Krivoruchenko M I, "Electromagnetic nucleon form factors in the extended vector meson dominance model," Submitted to Phys. Rev. D (manuscript DX13563).

[35] Kakorin I D, Naumov V A, and Samoylov O B JETP Lett. **119,** 813 (2024); Kakorin I D, Kuzmin K S, and Naumov V A, Eur. Phys. J. C **81**, 1142 (2021); Kakorin I D, Kuzmin K S, Naumov V A, Phys. Part. Nucl. Lett. **17,** 265 (2020).

[36] Abed Abud A et al. (DUNE Collab) Instruments 5 4 31 (2021)

measurements at different off axis positions (DUNE-PRISM). The third detector System for on-Axis Neutrino Detection (SAND), which will be placed on the beam axis and will consist of a straw-tube tracker (STT) placed inside a magnet.

JINR has already made a significant contribution in R&D of DUNE's near detectors. Group was responsible for the light readout development in liquid argon. To confirm the whole detector operation capability a 2x2 demonstrator was constructed for tests at the Fermilab NuMI beam. The demonstrator contains 4 prototypes of smaller TPC modules with dimensions of 0.67 x 0.67 x 1.81 m^3. These days, this prototype is taking data at Fermilab. A full-size near-detector module, the so-called Full-Scale Demonstrator (FSD) was built and exposed to the cosmic rays as well. The JINR team participated in manufacturing all these modules at Bern University under bilateral agreement.

Straw tube R&D was performed as a general technology study that can be used for modern straw tube detectors (SPD, SHiP, COMET, SAND). VBLHEP and DLNP physicists performed a series of tests at CERN with different prototype setups and electronics. All this will help for future projects to choose the optimal option for detectors.

Hyper-Kamiokande will have a very similar setup as the T2K experiment. Upgraded near detector complex of T2K will be used as it is for HyperK. The accelerator complex is planned to be upgraded to deliver a 1.3 MW proton beam. Instead of SuperK the bigger 258 kt far detector is under construction in a different location. All this together should provide higher sensitivity to the oscillation parameters than the T2K experiment has. The JINR team was involved in upgrading the T2K/HyperK near detector by methodical studies, installation and calibration of its new inner part, SuperFGD.

At present, the JINR is not an official member of the DUNE or HyperK projects and this proposal is, therefore, concentrated on the existing JINR team engagements in NOvA and T2K, which are approved to run at Fermilab and J-PARC, respectively, until 2027. During this time the JINR teams will continue physics analyses and elaborate on possible contributions to the future projects.

FASER and NA65(DsTau)

The FASER is an apparatus dedicated to searching for light, extremely weakly-interacting particles and studying neutrinos[37]. The experiment is located in the TI12 tunnel, which connects the Super Proton Synchrotron (SPS) and LHC tunnels, approximately 480m downstream of the ATLAS interaction point (IP) and aligned with the collision axis line-of-sight (LOS) (Figure 4). Charged particles produced in the forward direction at the ATLAS IP are deflected by LHC magnets, and FASER is also shielded from the ATLAS IP by about 100 m of rock and concrete. FASER's location therefore ensures that a high-intensity beam of neutrinos traverses the detector, while backgrounds are highly suppressed. The FASER detector is partially immersed in a magnetic field and consists of a passive tungsten-emulsion neutrino detector (FASERν), two scintillator-based veto systems, additional scintillators for triggering, a tracking spectrometer, a silicon pixel based pre-shower station, and an electromagnetic calorimeter (Figure 5).

The neutrino physics studies in the FASER experiment are mostly performed with a dedicated FASERν detector which consists of 730 layers of 1.1mm-thick tungsten plates interleaved with nuclear emulsion films. With a width of 25 cm and a height of 30 cm, it has a total mass of 1.1 tons. The emulsion films provide excellent position and angular resolution to identify CC neutrino interactions for all flavors of neutrino, though their extraction, scanning and analysis is time intensive.

The NA65 experiment as well as FASERν uses a nuclear emulsion detector. The technique demonstrated impressive progress over the past 20 years. The speed of the raw data processing (the readout of the tracking information from the emulsions by automatic scanners) has increased by more than 3 orders of magnitude and for the most powerful device (Hyper Track Selector[38] in Nagoya University) exceeds 5000 cm^2/hour. This makes large scale emulsion experiments, like FASERν and NA65, possible.

[37] Abreu H et al., JINST **19**, 05066 (2024).

[38] Yoshimoto M et al., PTEP **2017,** 102H01 (2017).

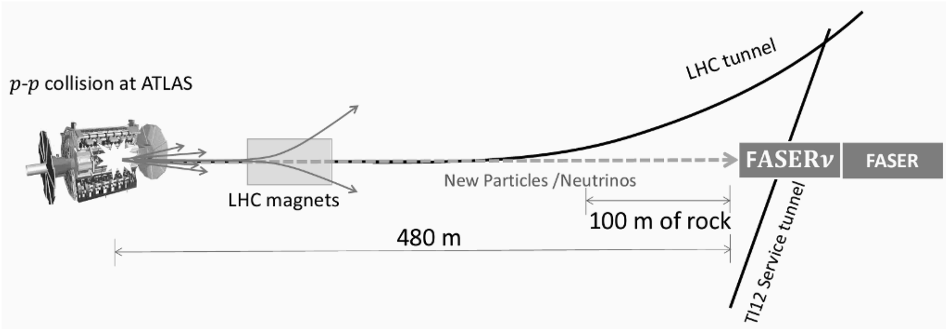

Figure 4. Location of FASER experiment at LHC.

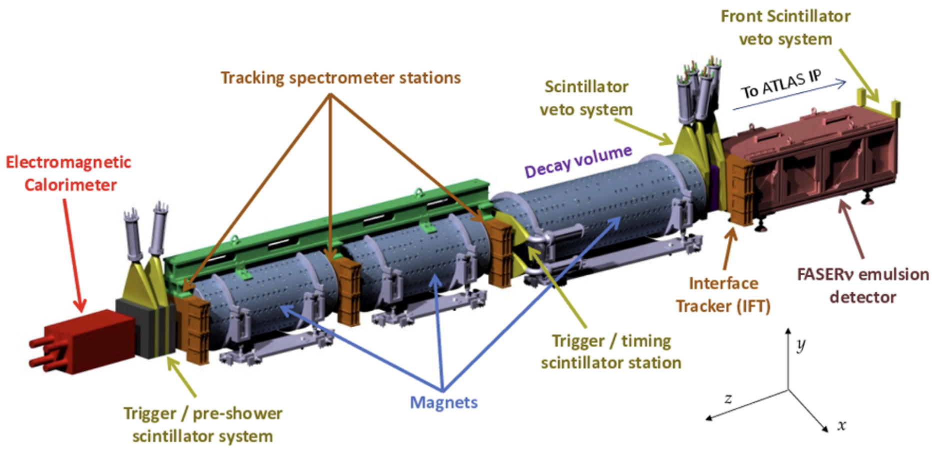

Figure 5. Layout of FASER experiment.

The raw data processing (emulsion scanning) is performed in Nagoya University by all the groups taking part in the project. The analysis of the digitized data (tracking, alignment, vertexing and physics analysis) is spread over several institutions since significant computing resources are required. The analysis performed with distributed computing and data storage resources is being managed by the JINR group both for FASERν and NA65 experiments.

The data analysis in emulsion detectors of FASERν and NA65 after digitization is similar to the one in the electronic experiments. However, it is very challenging due to a high event pile up and large track density in the emulsion detectors which exceeds 10^5 per cm^2. The software instruments used for emulsion data processing in previous experiments like OPERA (tracking, alignment, vertexing, decay search) need to be upgraded or the new tools developed. An experience gained by the JINR group during analysis of emulsion data in OPERA experiment will help efficiently participate in this activity as well as in the physics analysis.

Synergy between the experiments

The long-baseline neutrino experiments NOvA and T2K, solving the problem of measuring unknown oscillation parameters, have a similar setup. However, the detector designs and operating methods differ significantly, which leaves room for improving the results of the joint analysis, compared to the individual ones. Despite the ban on the simultaneous participation of the same people in the data analysis of both experiments, the presence of experts in the elements of analysis at JINR can play a synergetic role.

For example, one of the important systematics of measurement is neutrino-nucleon cross-sections, for which NOvA and T2K implement a different approach and use different Monte Carlo generators and their settings. In this situation, it seems reasonable to conduct mutual checks in each of the experiments and use these cross checks for better understanding of systematic uncertainties. The JINR project participants have the necessary experience to perform such work, both at the level of theoretical calculations and their implementation in Monte Carlo generators.

An example of the already demonstrated synergy between the experiments is the joint analysis presented in 2024. JINR employees have already participated in this analysis on the NOvA side, and it would be very productive for the next implementations to have, without violating the rules of the experiments, colleagues from JINR on the T2K side as well.

It should also be noted that both experiments analyze data in order to search for exotic objects and non-standard interactions. Discussion of theoretical and methodological approaches can serve to better understand the details of this work.

The synergy between the DsTau and FASER experiments is quite obvious, since both experiments are aimed at studying various aspects of the production and interaction of tau neutrinos using the nuclear photoemulsion technique. This technique, significantly developed in the OPERA experiment, is currently the most precise for measuring tracks of charged particles, and the participation of the JINR group in the OPERA work has created a good foundation for full participation in the DsTau and FASER experiments.

Techniques

The JINR groups already made valuable contributions to the NOvA and T2K detectors and at the current stage of experiments the JINR members are planning to focus on physics analyses. Some methodological contribution is expected for the FASER experiment.

The FASER detector consists of the neutrino detector, veto system, magnetic spectrometer, preshower and electromagnetic calorimeter. The last one is composed of 4 spare modules of LHCb ECAL. It was a fast, chip and rather efficient solution in order to prepare the setup on time before the beginning of Run 3. The calorimeter is primarily used for detection of electrons and gammas of high energy (up to TeV) from exotic particles decay – dark photons, axion-like particles and others. However, at present it has very poor transverse coordinate resolution, modest energy resolution, no longitudinal segmentation and the thickness not quite sufficient for measurements in TeV range.

The JINR group has a recognized experience in construction of the electromagnetic calorimeters. In particular, several options of the shashlik design and readout were already built for the COMPASS experiment[39] and suggested for further use in MPD and SPD detectors. Using this expertise (and even spare parts which were left) an electromagnetic calorimeter with parameters better corresponding to the requirements of FASER can be prepared. The project includes some R&D studies of the new FASER calorimeter and its possible use in the Run 3. The R&D can also provide valuable information for selection of the optimal calorimeter for the FASER2 detector[40] during Run 4.

Expected results

The following results are expected to be obtained with participation of the JINR team.

The NOvA experiment:

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[39] Chirikov-Zorin I et al., Nucl. Instrum. Meth. A **936**, 141 (2019).

[40] Feng J L et al., J. Phys. G **50**, 030501 (2023).

- measurement of neutrino mass hierarchy and reject CP conservation with $\leq 4\sigma$ and $\leq 2\sigma$ significance correspondingly;
- trigger monitoring and analysis preparations for supernova neutrino signal detection;
- a new restrictions on magnetic monopole existence with high gain data, higher statistics and updated trigger and analysis;
- measurements of atmospheric muon spectra for different conditions;
- first NOvA's oscillation analysis made with atmospheric neutrinos;
- ROC-Dubna and computing system operation.

The T2K experiment:
- the lepton CP phase δ_{CP} can be determined with an accuracy better than 23 degrees for all possible values of δ_{CP}, and CP violation can be found with statistical significance greater than 3σ (5σ) for 76% (57%) of the range of the parameter δ_{CP}.

JINR physicists will be involved in joint NOvA+T2K analyses which these two collaborations will agree to perform.

The NA65 (DsTau) and FASER experiments:
- In the FASER experiment, only a relatively small part of the data accumulated during the Run 3 has been processed until now, the analysis is ongoing, statistical error for the neutrino CC interaction cross section measurement will decrease. First tau neutrinos of high energy from LHC are expected to be detected with Run 3 data processed.
- In NA65 during the 2021-2022 run about 2×10^8 proton interactions in the detector have been recorded. In this data sample about 10^5 events of charm production and $\sim 10^3$ events of $D_s \rightarrow \tau \rightarrow X$ are expected to be present. The data analysis is ongoing and the results are expected both for charm physics and $D_s \rightarrow t$ process.

Risks

SWOT-Analysis

	Helpful	Harmful
Internal	**STRENGTHS** ● Already fully operational NOvA and T2K experiments with approval to run until 2027. ● The NA65 experiment accumulated data and is performing analysis. ● Fully operational upgraded near detector ND280 and beam line for T2K-II phase. ● Rich physics scope.	**WEAKNESSES** ● Systematic error sources depending on unknown cross-sections and detector features. ● Possible running time limitation due to beam line problems. ● Increasing muon background in TI12 tunnel may restrict FASERν exposure. Operation time of HTS is shared by several groups, availability is limited.
External	**OPPORTUNITIES** ● New physics existence ● Systematic errors reduction due to new measurements or theory	**THREATS** ● Major accident with detectors or beam hardware.

	improvement and, in case of T2K, due to modernization of the near detector ND280. ● Development of new methods and technologies.	● Unexpected change in plans of laboratories hosting the experiments due to significant budget cuts. ● Major changes in the world situation.

2.3 Estimated completion date

2030

2.4 Participating JINR laboratories

Dzhelepov Laboratory of Nuclear Problems (DLNP), Bogolyubov Laboratory of Theoretical Physics (BLTP), Mesheryakov Laboratory of Information Technologies (MLIT).

2.4.1 MICC resource requirements

Computing resources	Distribution by year		
	1st year	2nd year	3rd year
Data storage (TB) - EOS - Tapes	1 PB (Cloud)	1 PB (Cloud)	1 PB (Cloud)
Tier 1 (CPU core hours)			
Tier 2 (CPU core hours)			
SC Govorun (CPU core hours) - CPU - GPU			
Clouds (CPU cores)	1000	1250	1500

2.5. Participating countries, scientific and educational organizations

Organization	Country	City	Participants	Type of agreement
FNAL	USA	Batavia, IL	Alex Himmel + 3	JINR-FNAL agreement extension
University of California, Irvine	USA	Irvine, CA	Jianming Bian + 4	NOvA Collaboration
University of	USA	Minneapolis, MN	Matt Strait	NOvA

Minnesota				Collaboration
University of Minnesota Duluth	USA	Duluth, MN	Alec Habig	NOvA Collaboration
University of South Alabama	USA	Mobile, AL	Martin Frank	NOvA Collaboration
Queen Mary University of London	UK	London	Linda Cremonesi + 3	NOvA Collaboration
University of Florida	USA	Gainesville	Mayly Sanchez + 2	NOvA Collaboration
Caltech	USA	Pasadena	Ryan Patterson, Zoya Vallary + 2	NOvA Collaboration
The College of William & Mary	USA	Williamsburg	Patricia Vahle, Erika Catano-Mur	NOvA Collaboration
University College of London	UK	London	Ryan Nichol + 3	NOvA Collaboration
The Institute for Nuclear Research of the Russian Academy of Sciences	Russia	Moscow	Anatoly Butkevich + 1 Yuri Kudenko + 8	NOvA Collaboration T2K Collaboration
JAEA	Japan	Tokai	Matsubara T. + 5	T2K Collaboration
LPTHE	France	Paris	Giganti C. + 3	T2K Collaboration
CERN	Switzerland	Geneva	Jamie Boyd + 4	FASER and NA65 Collaborations
CERN	Switzerland	Geneva	Francesco Lanni Filippo Resnati	Neutrino Platform Agreement
Nagoya University	Japan	Nagoya	Osamu Sato + 2	FASER and NA65 Collaborations
Bern University	Switzerland	Bern	Akitaka Ariga + 2	FASER and NA65 Collaborations

Chiba University	Japan	Chiba	Akitaka Ariga + 3	FASER and NA65 collaborations

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).*

Fermi National Accelerator Laboratory (FNAL), Japan Proton Accelerator Research Complex (J-PARC), Nagoya University in Japan, European Center for Nuclear Research (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	20	1
2.	engineers	3.7	1
3.	specialists	-	1
4.	office workers	-	
5.	technicians	-	
	Total:	**23.7**	**3**

3.2. Available manpower

3.2.1. JINR staff

No.	Category of personnel	Full name	Division	Position	Amount of FTE
1.	research scientists	Alexander Olshevskiy	DLNP	head of department Project leader	0.6
2.	research scientists	Liudmila Kolupaeva	DLNP	deputy head of department Project leader	1.0
3.	research scientists	Oleg Samoylov	DLNP	head of sector Deputy project leader	0.7
4.	research scientists	Yury Gornushkin	DLNP	head of sector Deputy project leader	0.7

5.	research scientists	Nikolay Anfimov	DLNP	head of sector	0.3
6.	research scientists	Andrey Sheshukov	DLNP	senior researcher	0.5
7.	research scientists	Vyacheslav Tchalyshev	DLNP	senior researcher	0.2
8.	research scientists	Andrey Sadovsky	DLNP	senior researcher	0.5
9.	research scientists	Sergey Dmitrievsky	DLNP	senior researcher	0.8
10.	research scientists	Igor Chirikov-Zorin	DLNP	senior researcher	0.4
11.	research scientists	Alexander Antoshkin	DLNP	researcher	1.0
12.	research scientists	Alexander Selyunin	DLNP	researcher	0.3
13.	research scientists	Arseny Rybnikov	DLNP	researcher	0.2
14.	research scientists	Oleg Klimov	DLNP	researcher	1.0
15.	research scientists	Anastasia Bolshakova	DLNP	researcher	0.2
16.	research scientists	Svetlana Vasina	DLNP	researcher	1.0
17.	research scientists	Denis Korablev	DLNP	researcher	0.3
18.	research scientists	Anastasia Kalitkina	DLNP	junior researcher	1.0
19.	research scientists	Anna Gridina	DLNP	junior researcher	1.0
20.	research scientists	Anna Stepanova	DLNP	junior researcher	1.0
21.	research scientists	Vladislav Sharov	DLNP	junior researcher	0.2
22.	research scientists	Alexandra Ivanova	DLNP	research intern	1.0
23.	research scientists	Yuri Davydov	DLNP	head of department	0.3
24.	research scientists	Vladimir Glagolev	DLNP	head of department	0.1

25.	research scientists	Vyacheslav Tereschenko	DLNP	head of sector	0.1
26.	research scientists	Boris Popov	DLNP	senior researcher	0.5
27.	research scientists	Igor Suslov	DLNP	senior researcher	0.6
28.	research scientists	Vladimir Lyubushkin	DLNP	senior researcher	0.3
29.	research scientists	Vladimir Baranov	DLNP	researcher	0.4
30.	research scientists	Nikolai Khomutov	DLNP	researcher	0.3
31.	research scientists	Ilia Zimin	DLNP	researcher	0.4
32.	research scientists	Ilia Vasilyev	DLNP	researcher	0.3
33.	research scientists	Victoria Kiseeva	DLNP	junior researcher	0.6
34.	research scientists	Victor Matveev	BLTP	scientific leader of JINR, Academician of RAS	0.1
35.	research scientists	Gennadii Kozlov	BLTP	leading researcher	0.1
36.	research scientists	Vadim Naumov	BLTP	head of sector	0.5
37.	research scientists	Konstantin Kuzmin	BLTP	senior researcher, PhD	0.5
38.	research scientists	Igor Kakorin	BLTP	researcher, PhD	0.5
39.	research scientists	Dmitry Shkirmanov	BLTP	researcher, PhD	0.5
40.	engineers	Dmitry Fedoseev	DLNP	leading electronics engineer	0.2
41.	engineers	Vasily Gromov	DLNP	leading engineer	0.2
42.	engineers	Sergey Sokolov	DLNP	senior engineer	0.2

43.	engineers	Vladimir Kozhukalov	DLNP	engineer	0.2
44.	engineers	Alexey Chetverikov	DLNP	electronics engineer II cat.	0.2
45.	engineers	Kseniia Kuznetsova	DLNP	engineer	0.2
46.	engineers	Olesya Geytota	DLNP	engineer	1.0
47.	engineers	Albert Sotnikov	DLNP	engineer	0.8
48.	engineers	Olga Atanova	DLNP	engineer	0.2
49.	engineers	Svetlana Tereschenko	DLNP	engineer	0.2
50.	engineers	Nikita Balashov	MLIT	senior engineer	0.3
	Total				**23.7**

3.2.2. JINR associated personnel

There are 3 PhD students associated with the project. Their FTE is already accounted for in Table 3.2.1.

No.	Category of personnel	Partner organization	Amount of FTE
1.	Students	Moscow State University	1
3.	Students	Moscow Institute of Physics and Technology	2
	Total:		**3**

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.

660 k$ during three years

4.2 Extra funding sources

Expected funding from partners/customers – a total estimate.

—

Project Leader __________/L.Kolupaeva/

Project Leader __________/A. Olshevskiy/

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
		International cooperation	450	150	150	150
		Materials	90	30	30	30
		Equipment, Third-party company services	60	20	20	20
		Commissioning				
		R&D contracts with other research organizations	30	10	10	10
		Software purchasing	30	10	10	10
		Design/construction				
		Service costs (*planned in case of direct project affiliation)*				
Resources required	**Standard hours**	Resources				
		−the amount of FTE (Workshop and design bureau)	150	50	50	50
		−accelerator/installation,				
		−reactor,…				

Sources of funding	**JINR Budget**	JINR budget *(budget items)*	660	220	220	220
	Extra funding (supplementary estimates)	Contributions by partners Funds under contracts with customers Other sources of funding				

Project Leader ___________ /L. Kolupaeva/

Project Leader ___________ /A. Olshevskiy/

Laboratory Economist _________/________________/

APPROVAL SHEET FOR PROJECT / LRIP SUBPROJECT

TITLE OF THE PROJECT: Studying neutrino properties in accelerator experiments

SHORT DESIGNATION OF THE PROJECT: Accelerator neutrinos

PROJECT CODE: 02-2-1099-2-2015/2026

THEME CODE: 02-2-1099-2010/2026

NAME OF THE PROJECT LEADERS: Liudmila Kolupaeva, Alexander Olshevskiy

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	SIGNATURE	NAME	DATE
THEME / LRIP LEADER	SIGNATURE	NAME	DATE
PROJECT / LRIP SUBPROJECT LEADER	SIGNATURE	NAME	DATE
	SIGNATURE	NAME	DATE

APPROVED BY THE PAC	SIGNATURE	NAME	DATE