

NOvA/DUNE Project

Study of Neutrino Oscillations in NOvA/DUNE experiments

(JINR Participation)

Project extension for the period 2021-2023

A.Olshevskiy

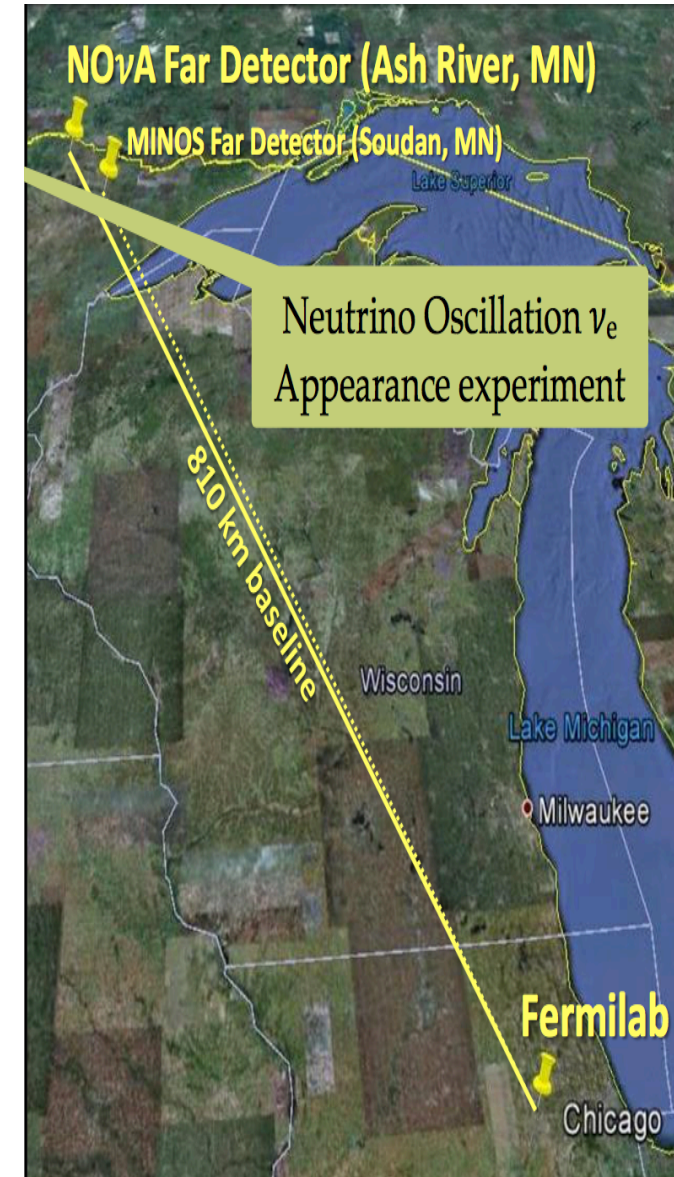
53rd Meeting of the PAC for Particle Physics

29 June 2020, JINR

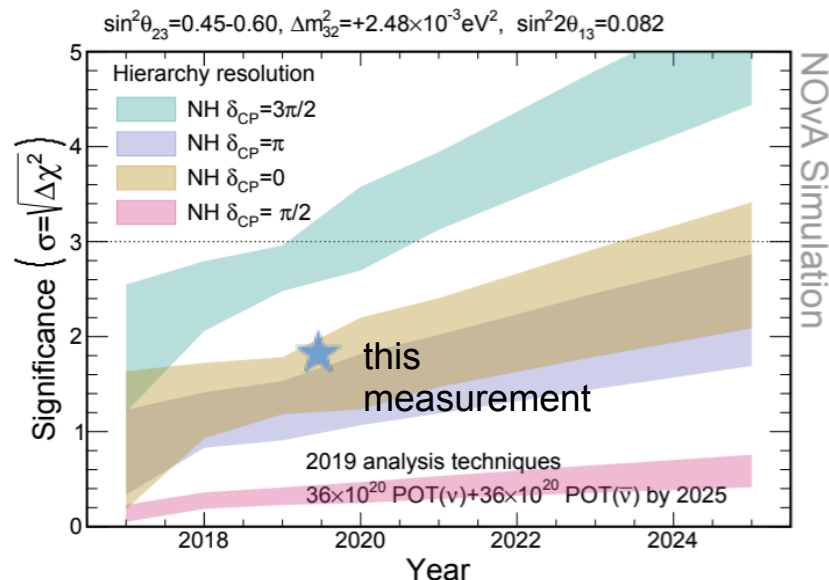
The NOvA experiment

Present NOvA Oscillation studies are based on exposure: 8.85×10^{20} (ν) and 12.33×10^{20} ($\bar{\nu}$) POT and resulted in:

- 4.4σ evidence for electron antineutrino appearance in the muon antineutrino beam.
- **1.9σ preference for the Normal Neutrino Mass Hierarchy**, exclusion of $\delta_{CP} = \pi/2$ in the Inverted Hierarchy at $> 4.0\sigma$.
- Best fit for the Normal Hierarchy $\delta_{CP} = 0\pi$, $\sin^2\theta_{23} = 0.56$, $\Delta m^2_{32} = +2.48 \times 10^{-3} \text{eV}^2$.
- Upper octant of $\sin^2\theta_{23}$ is preferred at 1.6σ , but still consistent with maximal mixing at 1.2σ .



Future NOvA/DUNE



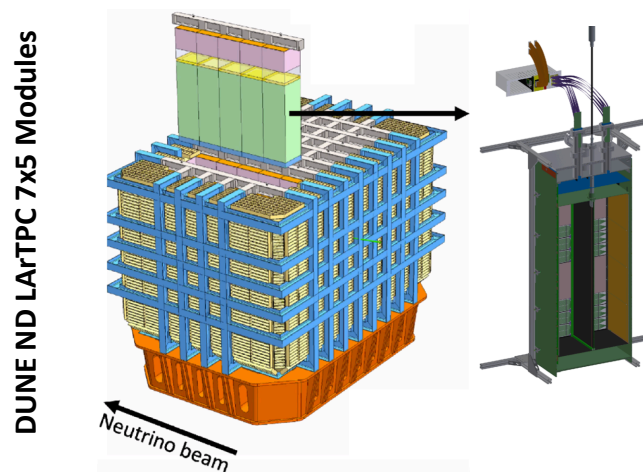
NOvA is approved to run until 2024 and 3-4 times increase statistics, which will provide:

- Possible 3-5 σ sensitivity to mass hierarchy
- Potential sensitivity to CP violation phase $> 2\sigma$

Later on, the DUNE project will come into operation providing significantly better sensitivity to the mass hierarchy and CP phase.

The JINR group is planning to continue its successful participation in NOvA and extrapolate the NOvA analyses and tools to the framework and conditions of DUNE.

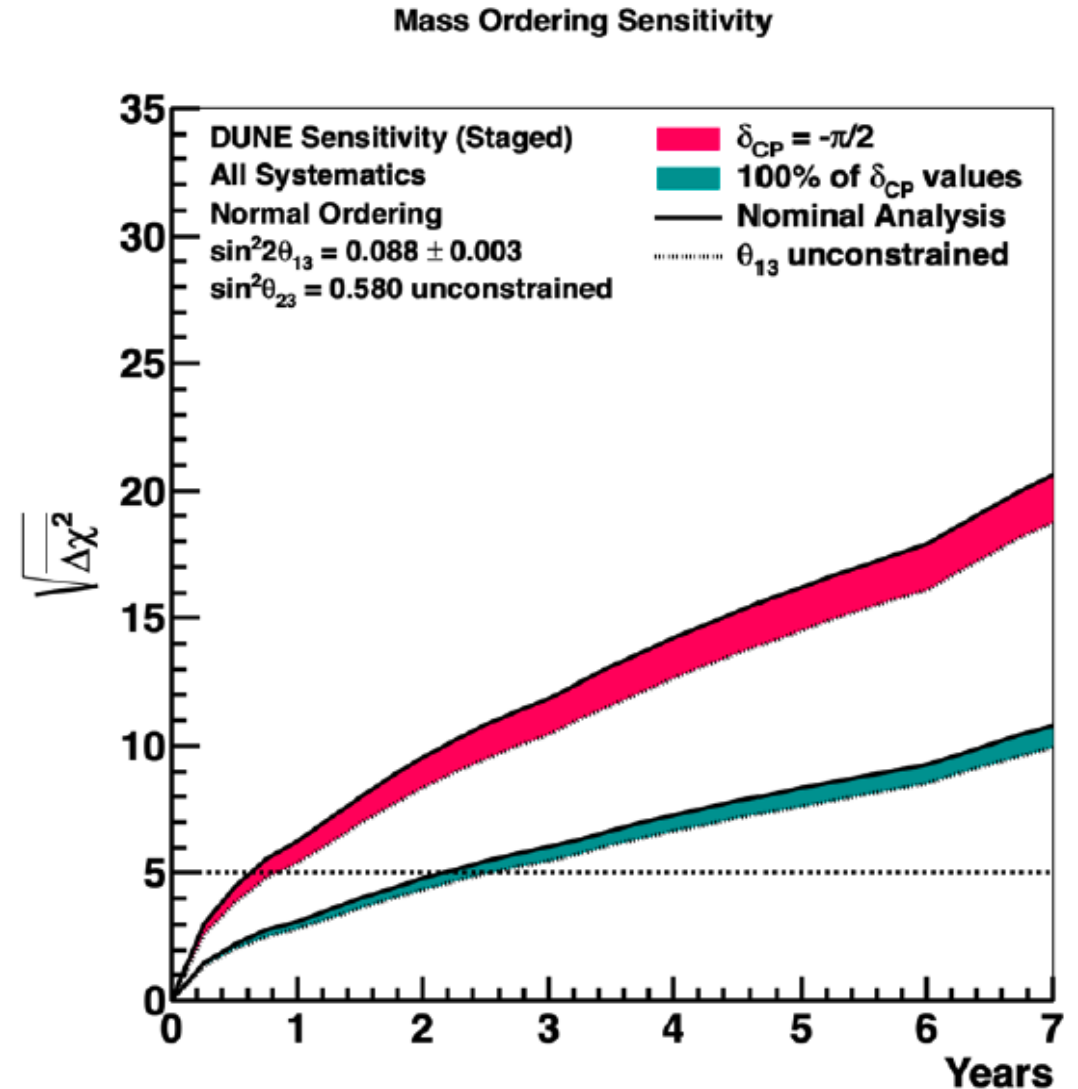
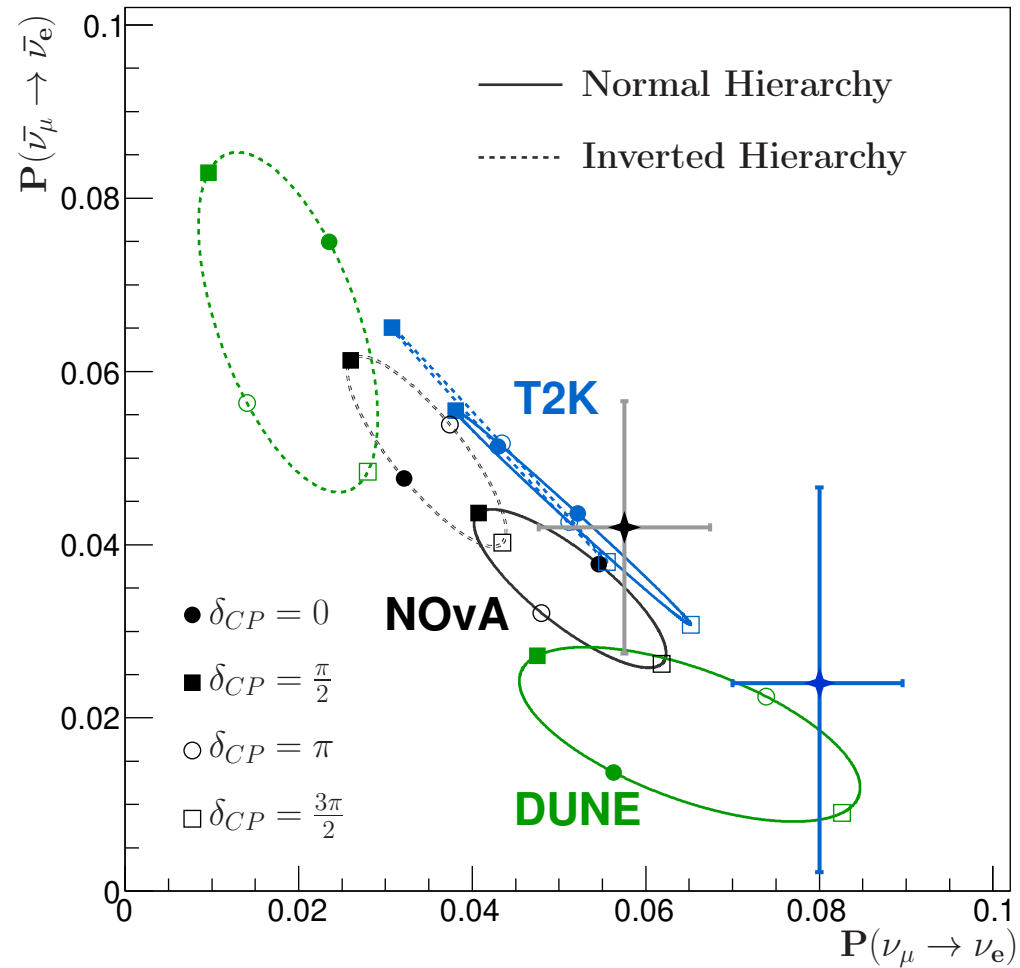
Light R/O for LArTPC of the DUNE ND



Moreover, the JINR group has already developed the Light Collection System of the Liquid Argon modules, which are constructed by the Collaboration for the DUNE Near Detector.

It is planned that the JINR responsibility will include the full construction chain of this system: Detectors, Front-End electronics, DAQ, Slow Control, Calibration system, etc.

Results and Prospects: NOvA, T2K and DUNE



JINR Tasks in brief (NOvA)

- Running Remote Operation Center at Dubna for JINR and Russian Institutes in NOvA.
- Measurements at NOvA test benches at JINR for detector response tuning.
- Computing resources for NOvA simulation and analyses.
- Calculation, modeling and measurement of neutrino interaction cross sections in the Near Detector.
- Oscillation analysis optimization and development of new analyses (search for Supernova, Magnetic Monopole, etc.).

JINR Tasks in brief (DUNE)

- R&D and Construction of the Light Collection System for the 2x2 Demonstrator of the DUNE Lar ND, including: detector, electronics, DAQ, slow control, etc.
- Development of the Computer infrastructure for the DUNE (Tier2) cluster at JINR
- Extension of the NOvA analyses and tools created at JINR to the DUNE framework.
- Development of Monte Carlo simulation (in particular, GENIE) and reconstruction software.

Project details (Personnel)

#	Name	Laboratory	Tasks	FTE
1	Anfimov Nikolay	DLNP	Methodical group leader	0.6
2	Antoshkin Alexander	DLNP	Test bench measurements; Slow monopole analysis; ROC-liaison;	1.0
3	Balashov Nikita	LIT	Computing	0.3
4	Baranov Alexander	LIT	Computing, cloud	0.1
5	Bilenky Samoil	BLTP	Oscillation theory	0.1
6	Butorov Ilya	DLNP	Software/analysis	0.5
7	Chalyshev Vyacheslav	DLNP	Mechanics	0.5
8	Chetverikov Alexey	DLNP	Mechanics/electronics engineering	0.7
9	Chukanov Artem	DLNP	Det., Light R/O Simulations	0.3
10	Dolbilov, Andrey	LIT	Computing, network support	0.1
11	Fedoseev Dmitry	DLNP	Mechanics/electronics engineering	0.7
12	Gromov Vasilii	DLNP	Slow-Control software	0.5
13	Kakorin Igor	BLTP	Det simulation, GENIE	1.0
14	Kalitkina Anastasia	UNC	Master student, data analysis, NOvA software release manager	1.0
15	Klimov Oleg	DLNP	Reconstruction, proton ID	0.6
16	Kolupaeva Liudmila	DLNP	PhD student, 3-flavor oscillation analysis	1.0
17	Korablev Denis	DLNP	Light R/O DAQ expert	0.4
18	Korsunov Vladislav	UNC	Bachelor student, sterile neutrino analysis	1.0
19	Kullenberg Christopher	DLNP	ND Physics, coh pion	0.6

20	Kutovskiy Nikolay	LIT	Computing hardware support	0.3
21	Kuzmin, Konstantin	BLTP	Det sim, cross sec theory	0.1
22	Kuznetsov Evgeny	LIT	Computing hardware	0.1
23	Kuznetsova Ksenia	DLNP	Analysis/measurements	0.7
24	Matveev Victor	BLTP	Theory, Coll management	0.1
25	Morozova Anna	DLNP	PhD student, Exotics, CR muons	1.0
26	Naumov, Vadim	BLTP	Osc and cross sec theory	0.3
27	Olshevskiy Alexander	DLNP	Coll and JINR tasks management, IB- rep	0.5
28	Petropavlova Maria	UNC	Master student, Supernova analysis	1.0
29	Petrova Olga	DLNP	Exotics, CR muons	1.0
30	Rybnikov Arseniy	DLNP	Software/analysis/measurements	0.7
31	Samoylov Oleg	DLNP	Det sim, co-convener; Det control, ROC-manager; JINR ana coordinations; Coll manag, deputy at JINR;	1.0
32	Selyunin Alexander	DLNP	Methodical group deputy: software, hardware, analysis, measurements	0.8
33	Sharov Vladislav	DLNP	Software/analysis	0.5
34	Sheshukov Andrey	DLNP	DAQ: software dev/support; DDT: supernova trigger; Exotics: SN detection; Detector control: ROC software;	1.0
35	Sokolov Sergey	DLNP	Mechanics/machinery	0.5
36	Sotnikov, Albert	DLNP	Hardware measurements and analysis	0.3
37	Vasina Svetlana	DLNP	Detector simulation	0.3
	TOTAL			21.2

The average age of the JINR NOvA team is ~35 years. There are: 1 bachelor, 2 master and 2 PhD students; 14 young research scientists also preparing PhD (5 of them are ready to present their thesis in the near future), 10 engineers, 4 staff members with PhD degrees and 4 professors.

Project details (Resources)

The following resources are requested for the proposed extension of the NOvA/DUNE project at JINR for the period of 2021-2023:

- 1) 25K\$ - Maintenance and upgrade of the ROC-Dubna. Office equipment (ageing desktop and laptop computer replacement) for team members.
- 2) 45K\$ - Laboratory equipment for tests. Additional hardware for tests, including DAQ and analysis computers.
- 3) 250K\$ - Construction of the Liquid Argon Light Collection system for the 2x2 ArgonCube DUNE ND Demonstrator.
- 4) 300K\$ - Computing infrastructure extension. We plan to add ~2PB of disk storage to the common NOvA/DUNE resources in the framework of the JINR neutrino experiments platform.
- 5) 300K\$ - money for visiting the NOvA and DUNE collaborating laboratories, participating in conferences and meetings.

Project details (SWOT)

	Helpful	Harmful
Internal	STRENGTHS <ul style="list-style-type: none">• Already fully operational NOvA experiment with the detector and beam parameters confirmed• Possibility to improve significantly in the next several years our knowledge on the neutrino Mass Hierarchy, CPV determination and other oscillation parameters, including θ_{23} octant determination• Rich non-oscillation program	WEAKNESSES <ul style="list-style-type: none">• Failure to deliver in time flux expected from NuMI for NOvA (and DUNE)• Low sensitivity in certain cases of Neutrino Hierarchy and CPV combinations• Systematic error sources depending on unknown cross sections and detector features
External	OPPORTUNITIES <ul style="list-style-type: none">• Supernova burst, new physics existence• Systematic errors reduction due to new measurements or theory improvement• Approved NOvA running until 2025 and changeover to DUNE after that	THREATS <ul style="list-style-type: none">• Major accident with detector or beam hardware• Unexpected change in Fermilab plans due to significant budget cuts or major changes in the world situation

Project details (Recent Reports, Seminars and Presentations)

1. [A.Antoshkin, E. C. Dukes, R. Ehrlich, M. J. Frank, E. Song, Subluminal Magnetic Monopole Search with NOvA, Madison, USA, 24 July - 1 August, ICRC 2019.](#)
2. [N.Anfimov. Light Readout System of the ArgonCube Liquid Argon Modular TPC for the Near Detector of the DUNE experiment. DLNP seminar, JINR, Dubna, Russia, 09 April 2020.](#)
3. [Nikolay Anfimov, Oleg Samoylov, Adam Aurisano, Alexander Antoshkin, Albert Sotnikov, Improvements in the NOvA Detector Simulation based on JINR stand measurements, INSTR2020, Novosibirsk, Russia, 24-28 February 2020.](#)
4. [Oleg Samoylov, Adam Aurisano, Nikolay Anfimov, Alexander Antoshkin, Albert Sotnikov, Improvements in the NOvA Detector Simulation based on JINR stand measurements, Boston, USA, 29 July - 2 August, DPF 2019.](#)
5. [Oleg Samoylov, Adam Aurisano, Nikolay Anfimov, Alexander Antoshkin, Improvements in the NOvA Detector Simulation based on JINR stand measurements, Nuclear Electronics and Computing 2019 \(NEC-2019\), 30 September — 4 October, 2019, Montenegro.](#)
6. [Oleg Samoylov, Adam Aurisano, Nikolay Anfimov, Alexander Antoshkin, Albert Sotnikov, Shiqi Yu, Improvements in the NOvA Detector Simulation based on JINR stand measurements, Adelaide, Australia, 4-8 November, CHEP 2019.](#)
7. [О.Б.Самойлов, Изучение нейтринных осцилляций в эксперименте NOvA, Сессия-конференция Секции ядерной физики ОФН РАН, Новосибирск, 10-12 марта 2020.](#)
8. [N.Balashov, I. Kakorin, V. Naumov Accelerating personal computations with HTCondor: generating large numbers of events with GENIE, Nuclear Electronics and Computing 2019 \(NEC-2019\), 30 September — 4 October, 2019, Montenegro.](#)
9. [A.Olshevskiy, Invited Neutrino Physics Lecture, JINR Summer school, 15 July 2019.](#)
10. [A. Sheshukov, Detecting neutrinos from the next galactic supernova in the NOvA detectors, Cape Town, South Africa, 21-28 February, 2020, CNNP2020](#)
11. [A. Sheshukov, Supernova triggering and signals combination for the NOvA detectors, Sudbury, Canada, June 2019, Supernova Neutrinos in the Multi-Messenger Era workshop \(SNEWS 2.0\)](#)
12. [A. Sheshukov, Detecting neutrinos from the next galactic supernova in the NOvA detectors, April 2019, Baksan school on Astroparticle physics](#)
13. [O. Petrova, East-West Asymmetry of Cosmic Ray Muons in the Far Detector of NOvA, ISAPP-Baikal, Bolshie Koty, Russia, 12-21 July 2018.](#)
14. [O. Petrova, East-west asymmetry effect in atmospheric muon flux in the Far Detector of NOvA, 16th Baksan School on Astroparticle Physics "Particles and Cosmology", 10-18 April 2019.](#)
15. [A. Selyunin. Development of the light collection module for the Liquid Argon TPC. INSTR2020, Novosibirsk, Russia, 24-28 February 2020.](#)
16. [L. Kolupaeva "NOvA's nue+numu oscillation analysis", PHYSTAT-nu 2019, CERN \(22-25.01.2019\)](#)
17. [L. Kolupaeva "Latest three-flavor neutrino oscillation results from NOvA", EPS-HEP 2019, 12.07.19](#)

Summary

- NOvA experiment provides important results by measuring oscillations with neutrino and antineutrino NuMI beam
- The JINR group in NOvA is contributing significantly to the experiment's results in different areas of analysis
- NOvA continues data taking until 2024 and it is proposed to prolong the project at JINR for the next three years period (2021-2023)
- It is also planned to extend the scope of the project activities by:
 - contributing to the R&D and construction of the Light Collection System for the DUNE Near Detector
 - preparing DUNE data analyses on the basis of the ones developed by JINR for NOvA
- The work in NOvA/DUNE project at JINR provides an excellent opportunity for visible contribution to the world-class physics