Theme: “Study of Neutrino Oscillations”

02-2-1099-2010/2023 (2026)

Projects: JUNO
NOvA/DUNE

+activities: Borexino/DS, DsTau/Faser(v)

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Request for synchronous extension in 2024-2026

Neutrino oscillation physics objectives

Oscillation Parameters:

Mass Ordering – *principal for $2\beta0\nu$, direct mass, SN, relic, …*

δ_{CP} – *Baryon Asymmetry of Universe (through leptogenesis)*

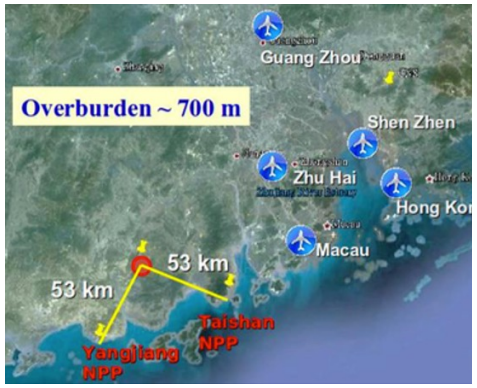
θ_{23} – *Models of Neutrino Mixing (e.g., in tribimaximal = 45°)*

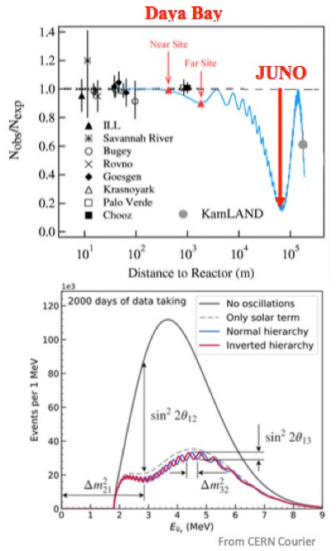
Mass Ordering (MO) and more

- *Reactor approach (JUNO)*

  Clean MO

  but tiny effect



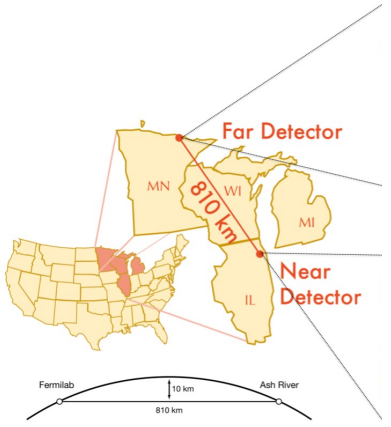


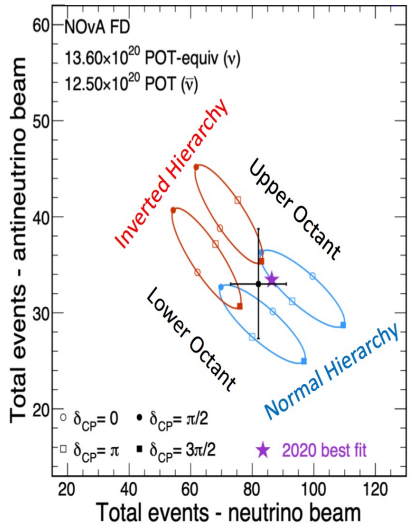
- *Accelerator approach (NOvA/DUNE)*

  MO degenerate with δ_{CP} and θ_{23}

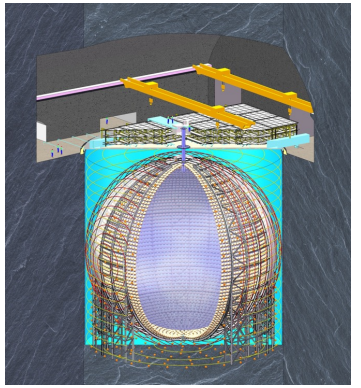
  but tuning L/E , $\nu/\bar{\nu}$ and measuring

  δ_{CP} and θ_{23} at the same time





JUNO



JINR group is working on:

- Top Tracker (modules reusing OPERA) +new mechanical design, DAQ and Analysis
- LPMT acceptance test and certification
- Design and production of the HV electronics for all JUNO PMT: ~20000 LPMT and ~27000 sPMT
- OSIRIS Earth Magnetic Field shielding
- Power supplies and test equipment for 4100 SiPM 32-sensor tiles of the TAO detector

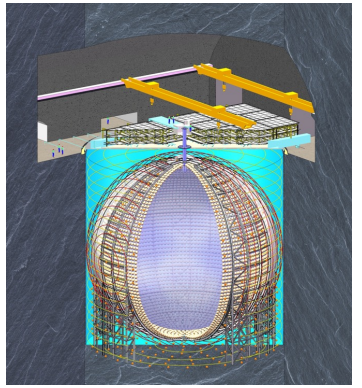
- The JUNO detector is assembled now

- Starting LS filling and data taking in 2024

- Analysis Software including event reconstruction and GNA.
- JINR is preparing to be: Raw Data Center, Regional Data Center and Simulation Production Data Center.

- Nominal goal of 3-4σ MO measurement
  - Require 3% energy resolution at 1MeV and 6 years of data taking
- Rich additional program, including:
  - Improve mixing parameters determination
  - Proton decay, SN neutrino, BSM
  - Geo-, atmospheric and solar neutrinos
  - Reactor antineutrino spectrum

Expected results (2024-2026)



1. Reconstruction

1. Reconstruction of muon tracks and electromagnetic showers with electronics simulation.
2. Reconstruction of clipping muons in central detector.
3. Efficiency and quality of reconstructed muon tracks.
4. Adaptation of muon track reconstruction procedure to real data.

2. VETO TT

1. The assembly and the commissioning of the Top Tracker detector of Juno setup will be completed.
2. First physics results on the measurement of the cosmic muons flux with help of the Target Tracker will be obtained.

3. Large PMTs

1. PMT testing with HV-units.
2. PMT installation to the JUNO Central Detector.

4. Filling and running JUNO

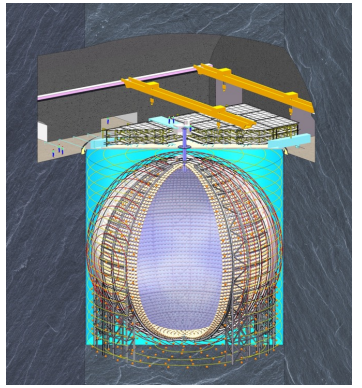
5. TAO

1. All SiPM for TAO are tested and installed to the detector.
2. Production and commissioning of the TAO SiPM power system 2024-2025
3. Filling and running TAO: late 2024 — early 2025.

6. Oscillation analysis

1. First measurement of neutrino oscillation parameters Δm^2_{31}, Δm^2_{21} and $\sin^2 2\theta_{12}$ in the JUNO experiment.
2. First constraints on the parameters of the sterile neutrino oscillations $\sin^2 2\theta_{14}$ and Δm^2_{41} based on the data from the detector TAO.

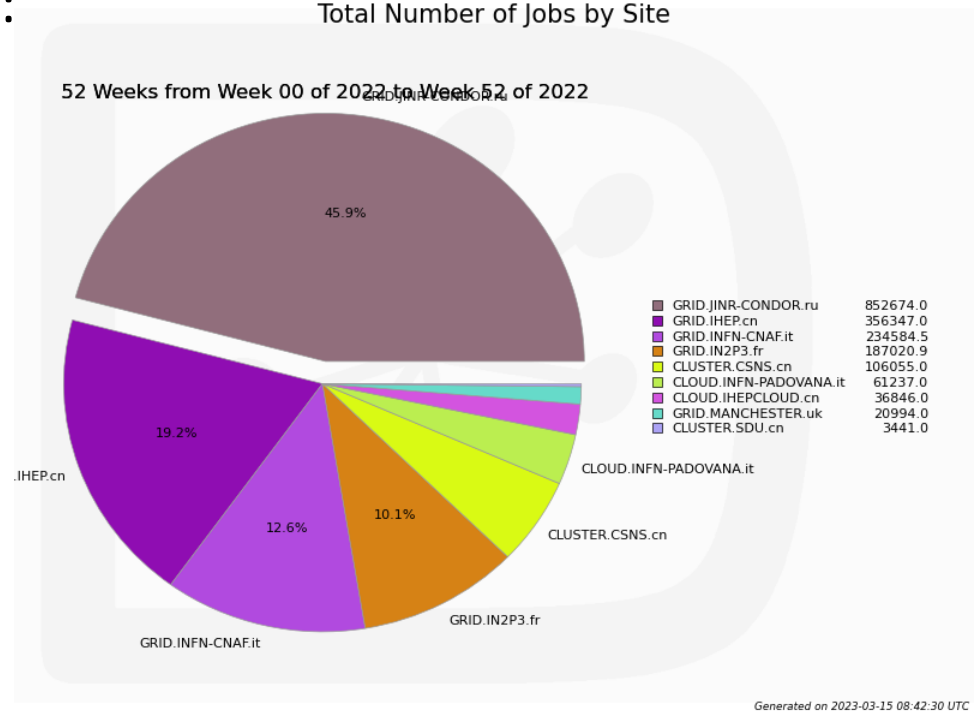
Project Resources

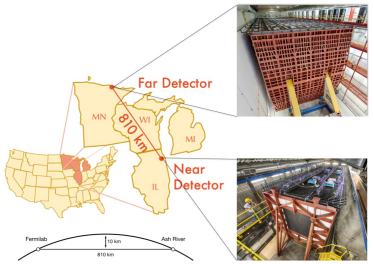


- Available Manpower at JINR:
  - **15.9 FTE + 5 Students**

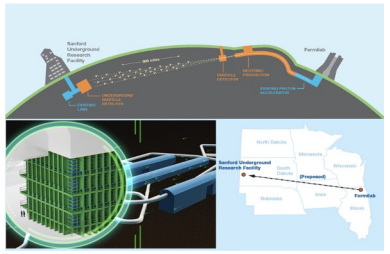
- Total requested cost of the project for 2024-2026:
  - **1300 k$**

- Significant contribution to the JUNO
  distributed computing infrastructure
  (regulated by the Computing MoU signed)
  - CPU ~ 3500/5000/6300
  - EOS 5000TB/year
  - Tapes 5000TB/year

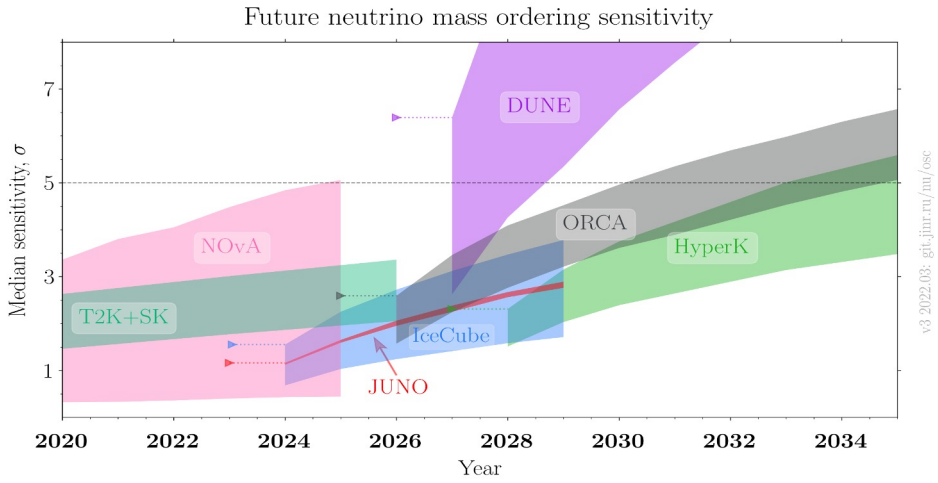




NOvA/DUNE



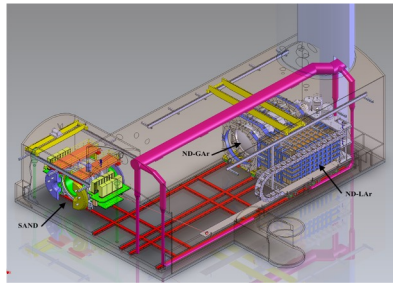
- NOvA is planning to run until 2026 and will double an exposure in ν and $\bar{\nu}$ modes
- This will allow (depending on values of other parameters) :
  - 2-4σ MO measurement and
  - < 2σ δ_{CP} measurement
- DUNE experiment can reach 5 σ MO determination just in the first 2 years



The following results are expected with participation of the JINR team in 2024-2026:

- Oscillation analysis of NOvA and NOvA+T2K
- Search for magnetic monopole
- Supernova trigger monitoring and analysis preparations
- Measurement of atmospheric muon spectra in different conditions
- NOvA atmospheric neutrinos oscillation analysis
- Scintillator properties characterization, namely, contribution of the Cerenkov light
- ROC-Dubna and computing system operation.

JINR in DUNE ND



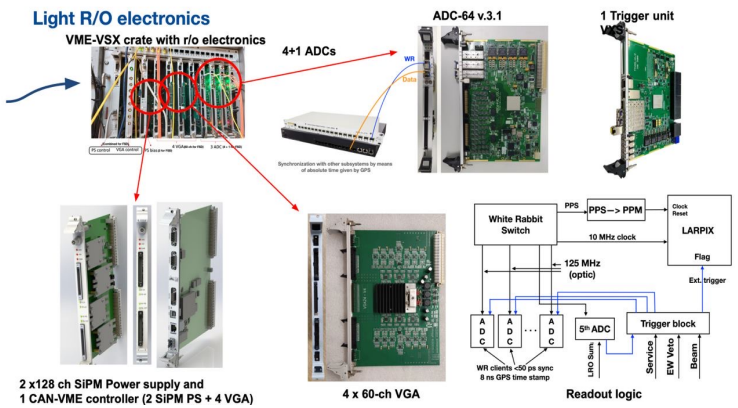
Main ideas of ND Lar:

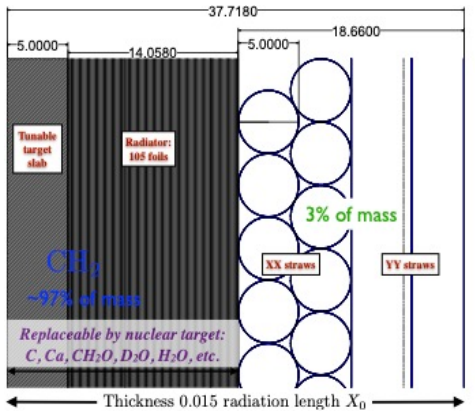
- Modular structure
- Pixelated charge readout
- High performance light readout

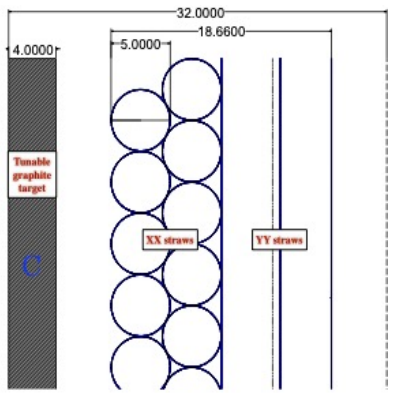
The JINR group is fully responsible for the latter one, constructing detector, electronics, DAQ, SC, etc.

SAND Straw-tube tracker:

- STT option was chosen over 3D based on JINR (VBLHEP) results
- VBLHEP group has joined DUNE and is planning to use existing experience of NA62, NA64, etc. for further development of straw technology for modern experiments (in particular, SPD)



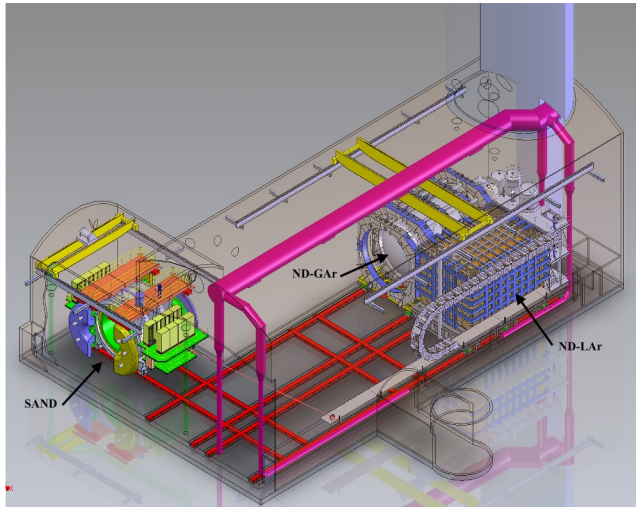


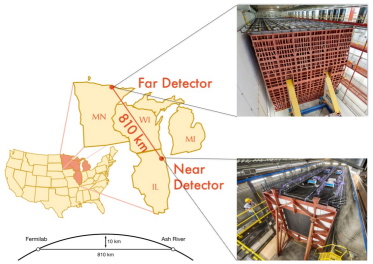


Expected results (2024-2026)

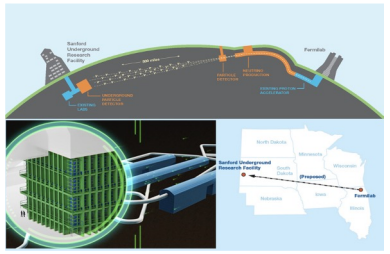
The DUNE experiment:

- Light Readout System development for NDLAr
- 2x2, Full Size Demonstrator tests and measurements at Bern and NuMI neutrino beam
- straw-tube prototyping, STT and electronics tests, preparations for production
- developing computing infrastructure and setup
- analysis preparations, taking an advantage of NOvA experience





NOvA/DUNE Project Resources



- Available Manpower at JINR:
  - **19.0 FTE + 8 Students**

- Total requested cost of the project for 2024-2026:
  - **1220 k$**

- Moderate contribution to DUNE distributed computing infrastructure
  - CPU ~ 1500
  - EOS 1500TB

Theme additional activities report

- Daya Bay – final result on Theta13 published. It is the most precise worldwide and will dominate precision during next ~15 years
- Borexino – refined result on CNO contribution and also completed the search for correlation of neutrino events in the Borexino detector in correlation with the most intense fast radio bursts
- DS – analysis of DS-50 data, R&D for DS-20k
- NA65/Faser(v) – data taking with emulsion detector in several configurations, preparation for data analysis.

Overall Theme Resources Request

- Available Manpower at JINR:
  - **40 FTE + 13 Students**
- Total requested cost of the theme 1099 for 2024-2026:

No.	Items of expenditure	Cost	Expenditure per year (thousands of the US dollars)		
			1st year	2nd year	3rd year...
1.	International cooperation	1290	430	430	430
2.	Materials	630	230	210	190
3.	Equipment, Third-party company services	290	110	90	90
4.	Commissioning	30	10	10	10
5.	R&D contracts with other research organizations	130	40	50	40
6.	Software purchasing	120	40	40	40
7.	Design/construction	15	5	5	5
8.	Service costs (*planned in case of direct affiliation)*	15	5	5	5
TOTAL:		**2520**	**870**	**840**	**810**

Theme results for 2021-2023

- Key publications – 46
- Conference reports – 49
- Defended diploma – 10
- PhD dissertations – 3

Conclusion

- During previously approved period of time the theme objectives were successfully fulfilled. Detector construction and preparation for data taking and analysis of the major mega-science class liquid scintillator detector **JUNO is well on track with the significant contribution from JINR**.
- The JINR physicists also made an **essential contribution to the results obtained by the NOvA experiment**, which will continue data taking through 2026 and will be substituted by significantly larger mega-science scale DUNE experiment, where the JINR team will apply experience gained in NOvA.
- For the DUNE project the JINR team is planning to make two main contributions to the near detector construction: **light collection system** of the liquid argon calorimeter modules and **straw tracker** of the on-axis detector. Both contributions are **well motivated by the JINR expertise and experience**.
- In addition, **several smaller-scale activities are also performed**, supporting continuation of Borexino and Dark Side data analysis and participation in the NA65/FASER(v) experiment.