New photodetectors and equipment

1. Goals of the experiment:

1a. Give a short description of the goals of the experiment - limited to ½ page.

Development of new photodetectors and the equipment for application in detector systems of neutrino experiments:

- development of methods for precise characterisation of large 20-inch PMTs for the Central Detector of the JUNO experiment.
- Studying of the NOvA detectors performance: electronics, photosensors, scintillator, etc.
- development of VUV light registration system in the Liquid Argon TPC in the Near Detector of the DUNE experiment (ArgonCube collaboration)
- Research and development in novel photodetectors.

1b. Explain what the project adds to the international scenario: limited to ½ page.

- A unique method of large PMT mass-testing for those experiments where precise energy resolution provided by the PMTs is critical (e.g., JUNO)
- Improvement of simulation for both near and far NOvA detectors: event reconstruction and neutrino energy determination.
- Main goal of the light detection in liquid argon is to provide a good trigger for the TPC in ND DUNE; combining measurements of light intensity and ionisation charge can also improve an event energy resolution.
- Photodetectors are very widely used in different applications. Development of new methods and measurement of critical characteristics provide a feedback to the producers of novel photodetectors and accelerates the progress in this area.

2. Contributions of the JINR group:

2a. Give an itemized list of the specific contributions of the JINR group in hardware (including use of JINR computing resources for the project), software development and physics analyses - limited to 1 page.

JUNO

- We developed and built up 3 scanning stations for precise PMT-testing. Two stations have been shipped and commissioned in China at JUNO PMT testing site and one is left at JINR for cross checks.
- So far, our shifters performed about 2000 PMT scans and spent 20 man-months for this.
- We developed and are managing the database for tested JUNO PMT raw and processed data.
- Currently we are developing and arranging a method for long-term stability tests of JUNO PMT.

NOvA

- Development of a testing stand with original NOvA Front-End electronics: we discovered an origin of the cross-talks on APD PCB (so-called Sag-effect), studied long signals shaping in FEB ASIC circuit to improve simulation of exotic physics signals (slow monopole search).
- We measured the NOvA liquid scintillator response to protons to define Birk's coefficient, which is very important for simulation of the true neutrino energy reconstruction.

DUNE

- R&D of light collection module (LCM) for light detection in Liquid Argon for ArgonCube. We developed LCM design based on WLS-fibers coated with TetraPhenyl Butadiene (TPB) shifter. The module is readout by SiPM and can operate in cryogenic environment providing total efficiency on VUV photon detection of 1-2%.
- We constructed a cryogenic stand to perform studies of LCM in Liquid Argon at JINR.

Photodetectors

- R&D in SiPMs: light detection, timing properties, cryogenic performance, studies of coupling with detectors (LCM, scintillating crystals, tiles, etc.)
- Absolute calibration of the photodetectors using small light pulses.

2b. Give a list of the responsibilities of JINR group members within the management structure of the collaboration, if any, giving the name of the JINR member, the managerial role and the appointment period.

1. Nikolay Anfimov — Level 3 manager in JUNO collaboration, PMT instrumentation, since 2015.
2. Alexander Olshevskiy — Level 2 manager, PMT instrumentation, since 2015 (JUNO).
3. Alexander Selyunin - Contact manager from JINR with the ArgonCube collaboration, since 2018.

3. Plans

Give a short description limited to ½ page of the JINR group plans (in data taking, analysis, detector R&D, upgrade activities…) till the end of the currently approved project.

In 2019-2020 it is planned:

JUNO

- Develop and commision robotic scanning station with 1 LED to perform zonal PMT studies with different wavelengths.
- Develop and perform long-term stability tests for a batch of the 20-inch PMT.
- Finish mass-testing of the 20-inch PMT.

NOvA

- Measure transparency, emission and absorption spectra of the NOvA liquid scintillator.
- Continue studies with NOvA electronics

DUNE

- R&D of light collection module (LCM) for light detection in Liquid Argon for ArgonCube. New more thin design, different shifters (ex. bis-MSB), improvement of light collection.
- Upgrade the cryogenic stand with purification system for liquid argon. Tests of new modules at JINR
- Assembling prototype of 12 modules and tests in ArconCube prototype at Bern University.

Photodetectors

- R&D in SiPMs: light detection, timing properties, cryogenic performance, studies of coupling with detectors (LCM, scintillating crystals, tiles, etc.)
- Improvement of Absolute calibration methods for Photodetectors.

4. Publications:

List the papers published in 2016, 2017 and 2018 in the refereed literature (no conference proceedings) in which the JINR group had a major contribution (e.g. author of the analysis, promoter of the experiment, corresponding author, realization of a key equipment etc.). Give title of paper, reference and describe in 1-2

sentences the JINR contribution. Mention the total number of papers published by the project in the same time period.

1. N. Anfimov et al. Measurement of Time-Resolution Parameters of a Silicon Photomultiplier. Approved for publishing. Physics of Particles and Nuclei Letters, 2019, Vol.16, No.1, pp.16-20. DOI: 10.1134/S1547477119010047.

   Work was completely performed at JINR.

5. PhD theses:

List the PhD theses completed within the last 3 years, or expected to be completed within 2019, by JINR students within the project, giving the student name, thesis title and graduation year.

N. Anfimov. R&D in novel photodetectors and their applications in physical experiment. In preparation, defence expected in 2019.

6. Talks:

6a. List the invited plenary talks given by members of the JINR group in 2016, 2017 and 2018 at international conferences, workshops…: give name and date of the Conference, title of talk and speaker name.

2017

a. N. Anfimov. Light collection module for Liquid Argon TPC. 3rd DUNE Near Detector workshop at CERN. 6-7 November 2017.

2018

A. N. Anfimov, State of art in development of silicon photomultiplier. Invited talk. Sixth International Conference "Engineering of Scintillation Materials and Radiation Technologies" - ISMART-2018. 9-12 october 2018, Minsk, Belarus
B. N. Anfimov, Convener of Section “Large scale characterization of SiPMs”. International conference on Advancements of Silicon Photomultipliers - ICASiPM, June 11-15 2018, Schwetzingen, Germany.

6b. Give a similar list for parallel talks.

2017

a. N. Anfimov. Large photocathode 20-inch PMT testing methods for the JUNO experiment. The International Conference "Instrumentation for Colliding Beam Physics", Poster, Novosibirsk, Russia, from 27 February to 3 March, 2017.
b. A. Selyunin. Light detection system of LAr TPC. The Dune Near Detector workshop, Bern, 09-10 June 2017.

2018

a. A. Rybnikov, Mass characterization of SiPM and modules for electromagnetic calorimeter ECAL0 of the COMPASS-II experiment. International conference on Advancements of Silicon Photomultipliers - ICASiPM, Poster, June 11-15 2018, Schwetzingen, Germany.

7. Group size, composition and budget.

7a. Present in a Table the list of JINR personnel involved in the project, including name, status (e.g. PI, researcher, post-doc, student, engineer, technician…) and FTE. Mention the total number of people in the collaboration.

		NOv*)	JUNO*)	DUNE/ArgonCube	PhotoDet	Total
Total members		??	627	N/A	16	
Members (JINR)		???	29	11	16	29
FTE (JINR)		1.0	5.4	3.6	3.7	13.7
Olshevsky A.G.	PI	0.4	0.4	0.1	0.1	1.0
Anfimov N.V.	PI	0.2	0.3	0.3	0.2	1.0
Butorov I.V.	engineer	0	0.5	0.5	0	1.0
Gromov V.O.	leding engineer	0	1	0	0	1.0
Korablev D.V.	researcher	0	0.2	0.2	0.3	0.7
Kuznetsova K.I.	engineer	0	0.2	0.6	0.2	1.0
Rybnikov A.V.	engineer	0.1	0.5	0.2	0.2	1.0
Selyunin A.S.	engineer	0	0.5	0.4	0.1	1.0
Sokolov S.A.	engineer	0	0.5	0.5	0	1.0
Fedoseev D.V.	engineer	0.1	0.4	0.3	0.2	1.0
Sharov V.I.	engineer	0	0.5	0.3	0.2	1.0
Sotnikov A.P.	leading engineer	0.2	0.2	0.2	0	0.6
Chirikov-Zorin I.E.	senior researcher	0	0	0	1.0	1.0
Chalyshev V.V.	senior researcher	0	0	0	1.0	1.0
Shutov V.B.	senior researcher	0	0.2	0	0	0.2
Sadygov Z.Ya.	senior researcher	0	0	0	0.2	0.2

*) The FTE of R&D for NOvA and JUNO is already taken into account in the relevant sub-projects.

7b. Indicate the expected changes in the group size, if any, till the end of the currently approved project.

		NOvA*)	JUNO*)	DUNE/ArgonCube	PhotoDet	Total
Members (JINR)		0	1	2	2	2
FTE (JINR)		0	0.5	0.8	0.7	2
Sharov V.I.	engineer	0	0.5	0.3	0.2	1.0
Chetverikov A.V.	engineer	0	0	0.5	0.5	1.0

*) The FTE of R&D for NOvA and JUNO is already taken into account in the relevant sub-projects.

7c. Present the JINR group budget from 2018 till the end of the currently approved project in a Table specifying the main budget items (equipment, computing, salaries, common funds, travel…)

Budget items			Total cost k$ (required resources)	Cost per year		
				2018	2019	2020
Materials and equipment	Testing Equipment		120	40	40	40
	Materials		45	15	15	15
Required resources	*norm. hours*	ОП JINR	*120*	*40*	*40*	*40*
	k$	Missions	45	15	15	15
Sources	Budget		210	70	70	70
	Non-budget					

7d. Indicate the use of JINR computing resources for the group and for the project if any.

N/A