I. Preamble

The Programme Advisory Committee for Nuclear Physics expressed deep sorrow at the passing away of Professor Adam Sobiczewski, an outstanding Polish scientist in the field of theoretical nuclear physics, a member of the PAC for Nuclear Physics since 1995.

The Chairperson of the PAC for Nuclear Physics, M. Lewitowicz, welcomed the PAC members, the ex officio members from JINR and members of the JINR Directorate.

The Chairperson presented an overview of the implementation of the recommendations taken at the previous meeting.

JINR Vice-Director M. Itkis informed the PAC about the Resolution of the 122nd session of the Scientific Council (September 2017) and the decisions of the Committee of Plenipotentiaries (November 2017). The PAC is pleased to note that the recommendations of the previous PAC meeting concerning JINR research in the areas of nuclear physics have been accepted by the JINR Scientific Council and Directorate.

II. Recommendations on the theme "Non-Accelerator Neutrino Physics and Astrophysics"

The PAC heard reports on the projects implemented within the theme "Non-Accelerator Neutrino Physics and Astrophysics" (03-2-1100-2010/2018) and proposals for their extension.

Project GERDA (G&M)

The PAC heard a report on the GERDA (G&M) project presented by K. Gusev, which is dedicated to search for the neutrinoless double-beta decay of ^{76}Ge with open Ge-detectors directly immersed in liquid argon. Today, Phase II of the experiment (2015–2021) is being performed by the GERDA collaboration. The most important feature of this phase is the liquid argon instrumentation surrounding the detector array to readout of scintillation light creating an effective active veto system. The total mass of the ^{76}Ge isotope is 38 kg. An unprecedented background level of 0.001 counts/(keV·kg·yr) has been achieved. The analysis of data collected in 2016–2017 allowed setting a new half-life limit with the world-best sensitivity on the neutrinoless double-beta decay of ^{76}Ge > $8.0 \cdot 10^{25}$ years. On reaching the planned exposure of 100 kg·yr, the half-life limit is going to be improved to > $1.4 \cdot 10^{26}$ years. A

part of the report was dedicated to the new generation ton-scale ^{76}Ge experiment LEGEND, which has been recently started. In this experiment, it is planned to achieve an ultimate sensitivity of 10^{28} years. The aim of this ambitious project is to answer the question about neutrino mass hierarchy.

Recommendation. The PAC recommends continuation of the GERDA project and participation in the LEGEND project in 2019–2021.

Project SuperNEMO

The PAC heard a report on the SuperNEMO project presented by Yu. Shitov. The long-term successful participation of JINR in the NEMO experiment has led to the obtaining of fundamental world-level results for the two-neutrino and neutrinoless double-beta decay of the enriched isotopes ^{48}Ca, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{116}Cd, ^{130}Te and ^{150}Nd (measurements at the NEMO-3 spectrometer). The new-generation SuperNEMO detector will have a modular design (20 modules) with the ability to simultaneously measure several isotopes at a sensitivity level to the half-life $T_{1/2}$ ($2\beta0\nu$) ≥ 10^{26} years. In the starting first module of the SuperNEMO (the demonstrator), 7 kg of ^{82}Se is used. JINR is playing a key role in the project, especially in constructing the calorimeter, the VETO system, modeling and data processing programs, and in developing methods for the purification of isotopes. The PAC expresses its confidence that JINR will continue to make a significant contribution to the construction of the SuperNEMO detector and its demonstrator.

Recommendation. The PAC recommends continuation of the SuperNEMO project in 2019–2021.

Project BAIKAL

The PAC heard a report and a proposal for extension of the project of deep-water investigations with the neutrino telescope at Lake Baikal (project BAIKAL) presented by I. Belolaptikov.

The presented second stage of the BAIKAL-GVD gigaton neutrino detector will be a new research infrastructure aimed primarily at studying astrophysical neutrino fluxes. The detector will use Baikal Lake water instrumented at depth with optical sensors that detect Cherenkov radiation from secondary particles produced in interactions of high-energy neutrinos inside or near the instrumented volume. The first step to the BAIKAL-GVD was finished in 2015, when the first demonstration cluster called “Dubna” was accomplished. During 2016–2017, the BAIKAL collaboration deployed two full-scale clusters with 576 optical modules. The current production and deployment rates allow two clusters to be installed annually. Thus, at the end of 2021, the collaboration is

planning to put into operation 10 clusters with 2880 optical modules. This will allow about 30 extraterrestrial events with energies above 100 TeV to be accumulated for detailed investigations of “IceCube signal”. The PAC underlines the important role played by the BAIKAL project together with the IceCube experiment to study the high-energy neutrino flux from all directions of the sky.

Recommendation. The PAC recommends continuation of the BAIKAL project in 2019–2023. The PAC expects a publication of the first results in due time.

Project DANSS

The PAC heard a report on the progress of the DANSS experiment with reactor neutrinos performed at the Kalinin Nuclear Power Plant (Kalinin NPP) and a proposal for its extension presented by V. Egorov.

The aim of the project is to construct a relatively compact neutrino detector which does not contain caustic, flammable or other dangerous liquids and therefore does not meet any restrictions against location close to an industrial power reactor. Due to such position, extremely high neutrino flux provides about 15000 IBD events (Inverse Beta Decay on a proton, i.e., $p+\overline{\nu_e} \rightarrow n+e^+$) in the 1 m^3 sensitive volume of the detector. In addition to the reactor monitoring, the detector is used for fundamental purposes, such as searching for short-range neutrino oscillation to a sterile state.

By today, the DANSS spectrometer has been assembled, launched and adjusted. The final answer about existence of the so-called “reactor anomaly” is expected to be obtained in 2018. During 2019–2021, it is planned, first, to widen the range of the DANSS sensitivity for the oscillation parameters and, second, to perform precise measurement of the neutrino energy spectrum as a function of time and fuel composition within 2-3 campaigns (these data will produce a basis for the reactor neutrino monitoring).

It is also proposed to contribute to a common JINR–NEOS (CUP IBS, Daejeon, Korea)–Neutrino4 (PNPI, Gatchina, Russia) construction of an additional detector near the SM3 research reactor at NIIAR (Dimitrovgrad, Russia) which could measure neutrino spectrum at 5-18 m distances, thus expanding the oscillation parameter region.

In addition, taking into account the accumulated experience, it is planned to develop and construct two new neutrino detectors S^3 (S-cube) with improved parameters based on another scintillator element. Being smaller, simpler and cheaper than DANSS, they will have better energy resolution and detect about 300-400 IBD events per day each. The first of them will be constructed by IEAP CTU (Prague) and

installed at the Temelín NPP (Czech Republic), whereas the second one will operate parallel to DANSS at the Kalinin NPP, thus providing more reliable reactor monitoring.

Recommendation. The PAC recommends continuation of the DANSS project in 2019–2021, including JINR's collaboration with the NEOS and Neutrino4 projects, as well as the development and construction of two small S^3 detectors.

Project GEMMA-III

The PAC heard a report on the progress of the GEMMA project experiments with reactor neutrinos performed at the Kalinin NPP and a proposal for their extension presented by A. Lubashevskiy.

The aim of the project is to investigate reactor neutrino properties using high-purity low-threshold germanium detectors. In particular, the experiments search for the magnetic moment of neutrino (MMN) and coherent elastic neutrino-nucleus scattering (CENNS). Currently, an experimental set-up is being constructed at the Kalinin NPP. Four low-threshold detectors with a total mass of about 1.6 kg are used. The achieved energy threshold is about 350 eV. Within the GEMMA-III project, it is planned to use four new low-threshold detectors (threshold ~ 200 eV) with a total mass of about 5.5 kg. The experimental set-up will be located under reactor core No. 3 at the Kalinin NPP where the distance from the centre of the core is only 10 m leading to an enormous antineutrino flux of $> 5 \cdot 10^{13}$ $1/(cm^2 \cdot s)$. The spectrometer is placed on a special lifting mechanism, which gives opportunity to vary online the antineutrino flux significantly and thus suppress the main systematic errors caused by possible long-term instability and uncertainty of background knowledge.

CENNS from reactor neutrinos can be observed for the first time in the current experiment. After all improvements it is planned to detect about 190 events from CENNS per day, which would allow using this process to study neutrino properties and to monitor the nuclear reactor. It is expected to reach sensitivity to the MMN at a level of $9 \cdot 10^{-12} \mu_B$ after several years of measurements and thus to reach the region of astrophysical interest.

Recommendation. The PAC recommends continuation of the GEMMA-III project in 2019–2021. The leading role of the JINR group in this experiment is highly appreciated.

Project EDELWEISS-LT

The PAC heard a report on the recent results of the EDELWEISS experiment presented by E. Yakushev. In the experiment, innovative cryogenic HPGe bolometers installed in a low-background set-up are used for the direct search of weakly interacting massive particles (WIMP) from the galactic halo considered to be the main candidates

for the role of dark matter. The main objective of the new phase of the experiment named EDELWEISS-LT is to search for spin-independent scattering on nucleons of the so-called light WIMPs. The relevance of this is rising, on the one hand, from non-evidence yet for SUSY at the LHC and, on the other hand, from new theoretical approaches favoring WIMPs with a mass below 10 GeV/c^2. The PAC notes with satisfaction that the participation in this project provides JINR an important access to the entire low-background infrastructure of EDELWEISS, including the LSM: one of deepest underground laboratories needed for the R&D of neutrino experiments at the Kalinin NPP.

Recommendation. The PAC recommends continuation of the research programme for the direct search of dark matter particles in the EDELWEISS-LT project in 2019–2021.

Summary on the theme "Non-Accelerator Neutrino Physics and Astrophysics"

The PAC heard a summary presented by E. Yakushev on the implementation of the theme "Non-Accelerator Neutrino Physics and Astrophysics" consisting of the above six projects. The theme is devoted to the studies of rare phenomena associated with the weak interaction by methods of modern nuclear spectroscopy. The rare processes under study include search for neutrinoless double-beta decay — the GERDA (G&M) and SuperNEMO projects; experiments with reactor antineutrinos — the DANSS and GEMMA-III projects; direct search for dark matter particles — the EDELWEISS-LT project; and investigations of high-energy neutrinos from space with the deep-water neutrino telescope at Lake Baikal —the BAIKAL-GVD project. The PAC is pleased to note the world-leading results obtained in all these projects. The PAC supports the general direction in which the theme is developing, when the participation in highly prestigious international projects provides an access to know-how for the development of home-based neutrino experiments at two basic facilities — the laboratories located at the Kalinin NPP and at Lake Baikal.

General recommendations. The PAC recommends that support of these experiments be rigorously continued. The PAC is aware about the lack of human resources at JINR in the BAIKAL experiment which can be a problem for a full involvement in the data analysis. It strongly advises to extend international contacts with the KM3NET collaboration to develop common synergies to become part of the ESFRI and APPEC roadmaps.

The PAC recommends that cooperation be supported with deep underground laboratories taking into account the necessity to find the adequate location for both LEGEND and full SuperNEMO detector. It underlines the necessity to continue the efforts to improve the local infrastructures at JINR and at Lake Baikal.

III. Status of the Factory of Superheavy Elements

The PAC heard a report on the progress of construction of the Factory of Superheavy Elements (SHE) presented by V. Semin and A. Popeko. The installation work for the DC-280 cyclotron is well advanced and is now planned to end in the first half of 2018. The start-up and adjustment is to be accomplished by mid 2018. The commissioning of the DC-280 accelerator should start by September 2018. The construction of the experimental set-ups including the target system, separators and detection systems has made very important progress. In particular, a new gas-filled recoil separator has been manufactured and delivered to Dubna; its assembly is scheduled for January-March 2018. First test experiments are planned for October-November 2018. In addition to the technical work, an important effort of FLNR and JINR concentrates on the licensing process, which must be accomplished to begin experiments on the synthesis and studies of superheavy elements.

The PAC would like to congratulate the FLNR team for the well-thought out decisions concerning the continuation of the operation of U-400 for several years in parallel to the operation of experiments at GFS-1. Both experiments, spectroscopy and reaction studies at SHELS and new elements at GFS-1, are complementary.

Recommendations. In order to meet the deadlines for commissioning and first experiments at the SHE Factory, the PAC recommends that the JINR and FLNR Directorates provide maximum possible resources to accomplish the work for all the systems of the accelerator, the separator, the target and detection units in 2018. The licensing of the facility, which is today on the critical path, should be carefully followed by the management. Following the recommendations taken at the previous meeting, the PAC would like to hear a presentation on the methodology for the quality control for the construction and commissioning of the SHE Factory subsystems at the next PAC meeting.

IV. Fragment-separator ACCULINNA-2

In the Flerov Laboratory of Nuclear Reactions, the ACCULINNA-1 fragment separator was used during many years to study exotic nuclei far from the stability line.

In 2016, a new fragment separator ACCULINNA-2 was commissioned in the beam line of the U400M cyclotron. With the ^{15}N primary beam, the new fragment separator was tested in 2016 and 2017 to produce various secondary beams of radioactive isotopes. Intensities of the obtained secondary beams were 25 times higher than those obtained with the previous facility ACCULINNA-1. Thus, ACCULINNA-2 becomes the basic facility to study exotic nuclei at the Flerov Laboratory. The first experiments for the new facility are proposed to study ^{7}H, ^{13}Li, ^{17}Ne, ^{26}S decaying via 2p, 2n and 4n emissions.

Recommendation. The PAC fully supports the experimental programme for the year 2018 with the ACCULINNA-2 fragment separator. In the first measurements, a deuterium polyethylene target is planned to be used, and the PAC recommends installation of the gas target system to the ACCULINNA-2 experimental area.

V. Recommendations on the concluding theme "Theory of Nuclear Structure and Nuclear Reactions" and for a new theme "Theory of Nuclear Systems"

The PAC took note of the report presented by N. Antonenko on the concluding theme "Theory of Nuclear Structure and Nuclear Reactions" (01-3-1114-2014/2018) and of the proposal for a new theme entitled "Theory of Nuclear Systems". The PAC highly appreciates the results obtained in the main research directions: structure of nuclei far from stability, nucleus-nucleus collisions at low energies, fusion dynamics, few-body systems, nuclear dynamics at relativistic energies, properties of hot and dense nuclear matter. Outstanding results have been achieved by designing a large variety of models and innovative effective numerical methods. The PAC appreciates that the topics are strongly connected with the main experimental activities occurring in the main facilities at JINR and abroad. The PAC notes the smooth transition to the new theme "Theory of Nuclear Systems" which promises to be solidly connected with the physics items of strong interest for the SHE Factory and ACCULINNA-2 facilities at JINR and for other facilities operating or in the commissioning phase such as FAIR, SPES, HIE-ISOLDE, SPIRAL2, and ELI-NP. The PAC also appreciates the educational activities of BLTP.

The PAC supports continuation of nuclear theory activities under the new theme "Theory of Nuclear Systems" that should continue incorporating complex and broad views on the various aspects of nuclear structure and reactions in close synergy with the JINR experimental programme.

Recommendation. The PAC recommends closure of the theme "Theory of Nuclear Structure and Nuclear Reactions" after its completion in 2018 and approval of the new theme "Theory of Nuclear Systems" for 2019–2023. The PAC also recommends that

international cooperation be tightened with other theory groups, in particular with the ECT* centre in Trento (Italy).

VI. Scientific reports

The PAC heard with interest the report “Study of vorticity and hyperon polarization in heavy-ion collisions within the NICA energy range” presented by V. Toneev.

The PAC heard with great interest the report “Application of multinucleon transfer reactions to the synthesis of neutron-rich nuclei” presented by A. Karpov. His extended scientific presentation concerns a multinucleon transfer reaction model which has the capabilities to reproduce rather well the existing experimental data, including the experiments performed at JINR by the Flerov group. It is demonstrated that solving the Langevin equations, with well-controlled parameters, will be useful to make predictions of very neutron-rich nuclei that might be more easily synthesized than with fragmentation processes. It is interesting to note that the model of Karpov, Zagrebaev, Greiner and collaborators appears to be much more reliable than the commonly used GRAZING Code of the Torino group to predict yields of exit channels far from the projectile-like and target-like nuclei.

The PAC heard with great interest the report “Neutron activation analysis of arsenic and mercury content in human remains of the XVI-XVII centuries from the Moscow Kremlin necropoleis” presented by A. Dmitriev. The PAC recognizes how the application of this nuclear technique can be so powerful in producing sensitive data as a strong background for historical interpretations. The PAC encourages the team to continue such special work by finalizing the present analysis and applying this method to other cases, for instance in fine arts.

VII. Poster session

The PAC appreciated the high quality of presentations of new results and proposals by young scientists in the field of nuclear physics research. The best posters selected are: “Sensitive neutron detection method using iodine-containing scintillators” presented by D. Ponomarev, “Utilization of the (p,4n) reaction potential for the production of medical isotopes with medium-energy protons: radionuclide generator ^{90}Mo→^{90}Nb” presented by A. Marinova, “Active background suppression using argon scintillation for the GERDA Phase II and the LEGEND experiment” presented by E. Shevchik.

The PAC recommends the poster “Sensitive neutron detection method using iodine-containing scintillators” for presentation at the session of the Scientific Council in February 2018.

VIII. Miscellaneous

The PAC notes the large amount of work carried out by the authors of the E&T project to develop methods for studying the main nuclear physics parameters of the uranium assembly “Quinta” (neutron field, plutonium production time, energy yield of the assembly, transmutation rates of minor actinides) and to prepare the new programme with the uranium massive BURT target. The target has been recently installed at DLNP for irradiation with the Phasotron beam.

Recommendation. The PAC recommends that the results obtained with the “Quinta” assembly and the future programme with the BURT target be assessed at a dedicated review meeting to be organized by the JINR Directorate.

IX. Visit to DLNP

The PAC thanks the Directorate of the Dzhelepov Laboratory of Nuclear Problems for the organization of the visit to this Laboratory.

X. Next meeting of the PAC

The next meeting of the PAC for Nuclear Physics will be held on 20–21 June 2018.

Its tentative agenda will include:

– reports and recommendations on themes and projects to be completed in 2018;
– consideration of new projects;
– poster presentations of new results and proposals by young scientists in the field of nuclear physics research;
– scientific reports.

M. Lewitowicz
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for Nuclear Physics

N. Skobelev
Scientific Secretary of the PAC
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