RECOMMENDATIONS OF THE JOINT SESSION OF THE PAC FOR PARTICLE PHYSICS AND THE PAC FOR NUCLEAR PHYSICS FOR THE ASSESSMENT OF JINR NEUTRINO PROJECTS

At its 123rd session, the Scientific Council approved the proposal of both PACs to have joint sessions for the evaluation of the JINR neutrino projects. Following that, on January 21, 2021, the PAC for Particle Physics and the PAC for Nuclear Physics held a joint session for the evaluation of five neutrino projects under the theme “Non-Accelerator Neutrino Physics and Astrophysics”.

Following the guidelines outlined by JINR Director G. Trubnikov, the evaluation aimed at classifying the various projects into three categories, using the scheme adopted in the previous joint session in January 2019, based primarily on the scientific merit of the project, and the performance, impact and visibility of the JINR group. For that, the project leaders were requested to answer a short common questionnaire prepared by representatives of the two PACs. Each project was reviewed by one referee from the PAC for Particle Physics and one from the PAC for Nuclear Physics. The questionnaire itself, the answers to the questionnaire and the referee reports have been uploaded to the Indico webpage of the joint session. The final evaluation of each project was made taking into account the opinions of the two relevant referees and the subsequent discussion of the project at the joint session of the two PACs.

GERDA (LEGEND) project

The PAC heard the report presented by K. Gusev on the GERDA (LEGEND) project dedicated to searching for the neutrinoless double-beta decay of ^{76}Ge with open Ge-detectors directly immersed in liquid argon. The GERDA project is carried out at Gran Sasso in Italy by a large international collaboration.

After reaching the planned exposure of 100 kg yr, Phase II of the GERDA experiment (2015-2020) was completed. An unprecedented background level of $5 \cdot 10^{-4}$ counts/(keV kg yr) was achieved. The analysis of the full GERDA data set of 127.2 kg yr collected in Phase I and II enabled setting a new world-best half-life limit on the neutrinoless double-beta decay of ^{76}Ge > $1.8 \cdot 10^{26}$ years.

The impressive GERDA performance gives confidence on the feasibility of the new generation ton-scale ^{76}Ge experiment LEGEND. LEGEND is foreseen to proceed in two

phases as was the case for GERDA. The first phase will operate with up to 200 kg of germanium detectors inside the existing GERDA cryostat. It is planned to achieve a sensitivity of 10^{27} years thus requiring to improve the present background by factor 5. The full-scale project with 1 t of ^{76}Ge aims for a sensitivity of 10^{28} years by reducing the background by a factor 10 and then for a potential answer to the question about neutrino mass hierarchy.

Recommendation. The PAC acknowledges the important role played by the JINR group in the GERDA (LEGEND) experiments and recommends continuation of this project in 2022–2024 with A ranking.

SuperNEMO project

The PAC heard the report presented by V. Tretyak on the SuperNEMO project dedicated to the search for neutrinoless double beta decay (0v2β) employing tracker-calorimeter techniques, which allow the reconstruction of angles and energies of the betas for each event. The long-standing participation of DLNP JINR in the first-generation NEMO-2/3 experiments has led to world-class results for the two-neutrino and neutrinoless double-beta decays of the ^{48}Ca, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{116}Cd, ^{130}Te and ^{150}Nd isotopes.

With SuperNEMO, a new generation of the detector is under construction at LSM (Modane) with a design capability of measuring of the order of 100 kg of various isotopes, for maximum sensitivity of the ultimate detector to half-lives $T_{1/2}(0\nu2\beta) \geq 10^{26}$ years. The “SuperNEMO Demonstrator” is the first module (out of twenty) now in commissioning phase that will be ready in 2022 to search for 0v2β decays in ~ 7 kg of enriched ^{82}Se. The JINR group plays an important role in the project, notably in the construction of the passive shielding, the VETO system, the calorimeter, software and data handling, and in the development of radiochemical purification methods.

Despite the achievements, the PAC notes that the present generation of the project features several years of delay, for which the group provided convincing justifications, but that anyhow hamper the potential impact of the experiment within the harsh international competition already aimed at high-sensitivity third-generation detectors exploiting Germanium and Xenon. Nevertheless, the tracking-calorimeter capability, as well as the free selectivity for any of the candidate isotopes, could make SuperNEMO contributing to the assessment of a possible 0v2β signal once found by other searches.

Recommendation. The PAC acknowledges the potentialities of the technique used by SuperNEMO and recommends continuation of this project in 2022–2024 with ranking B, encouraging the proponents to set up a focused and timely productive group for the exploitation of the Demonstrator detector.

DANSS project

The PAC heard the report presented by Yu. Shitov on the DANSS reactor neutrino project at the Kalinin Nuclear Power Plant dedicated to the search for sterile neutrinos. DANSS safely installed a compact neutrino spectrometer near the reactor and in five years of operation during 2016–2020, registered world record statistics of four million reactor antineutrinos (one million events per year, or five thousand per day). This allowed DANSS to obtain world-class results among which:

- No significant effect of oscillations of reactor antineutrinos into sterile neutrinos after analysing most of the collected statistics (~ 3M events). As a result, the largest area (in comparison with competitors) of the parameter phase space ($\sin^2(2\theta_{14})$, Δm_{14}^2) of possible oscillations was excluded, including the point of the best fit of the reactor antineutrino anomaly, excluded at a level of more than 5 σ.
- Ability to monitor the reactor power with a statistical error of ~ 1.5% in two days of measurements, and to determine the composition of the nuclear fuel (Uranium /Plutonium ratio), thus confirming the applicability of the proposed technology for reactor control.

The main task of the next stage of the project is the upgrade of the DANSS-2 spectrometer with a factor of two better energy resolution, which will allow expanding significantly the tested phase space region in the search of sterile neutrino, including the region ($\sin^2(2\theta_{14}) \sim 0.25$, $\Delta m_{14}^2 \sim 7$ eV^2) where the NEUTRINO-4 experiment reported a signal and obtaining a better-quality spectrum of reactor antineutrinos, which is important for solving the spectral anomaly problem.

In addition, it is planned to continue working on the development of a mini-spectrometer S^3 (S-cube) (~ 64L with improved detecting elements). Such a detector will register ~ 300-400 neutrinos per day and, together with DANSS-2, will help to better understand the systematics of the used measurement method.

DANSS is a relatively small collaboration. The operation in a nuclear reactor restricts the possibilities to open up the DANSS project to a more international collaboration or a remotely controlled operation.

Recommendation. Compared with other neutrino experiments, the DANSS experiment is unique in its capability to operate close to a high flux nuclear reactor and to produce data of high scientific value with unprecedented statistics. The PAC recommends continuation of the DANSS project in 2022–2024 with ranking A.

νGeN (GEMMA) project

The PAC heard the report presented by A. Lubashevskiy on the proposal for the extension of the νGeN (GEMMA) project, which is performed by a JINR group at the Kalinin Nuclear Power Plant. The measurements are focused on studying reactor neutrino properties such as the search for neutrino magnetic moment and the coherent elastic neutrino-nucleus scattering, a process recently identified for the first time with accelerator neutrinos.

The experiment makes use of high-purity low-threshold Germanium detectors (200 eV) of low background of 1 cts / (keV kg day) and total mass up to about 5.5 kg, placed at a short distance from the reactor centre, under a flux exceeding $5 \cdot 10^{13}$ antineutrinos/(cm^2s). The 50 m w.e. overburden and the movable spectrometer, which allows varying the antineutrino flux, are qualifying features of the project. The experiment is in its first phase of data taking.

Recommendation. Despite delays in the realization of the project and a consequent reduced scientific production, the PAC acknowledges the strong commitment of the JINR group. The group is capable to conduct the research autonomously, as well as within the strong international competition, in particular, concerning the observation of neutrino coherent scattering. The PAC recommends continuation and full financing of the νGeN project in 2022–2024 with ranking B.

EDELWEISS-RICOCHET project

The PAC heard the report presented by E. Yakushev on the latest results of the EDELWEISS experiment and on the continuation of its research programme with new cryogenic HPGe detectors-bolometers, that will be expanded to include Coherent Elastic Neutrino(ν)-Nucleus Scattering (CEνNS) studies. The PAC notes the successful development of bolometer detectors, which will enable EDELWEISS-RICOCHET to carry out high precision spectrometric measurements at energies down to very low ones

(with an energy threshold below 100 eV) where the manifestation of new physics in the electroweak sector is expected to be seen as distortions in the recoil nuclei energy spectrum induced by CEνNS.

The first phase of the RICOCHET programme, with a large (kg scale) experiment, will be carried out at the ILL research reactor (Grenoble, France). At the same time, the newest detectors will continue to be used at EDELWEISS for the direct search of Dark Matter particles from the galactic halo in the low-mass WIMP region (1 GeV/c^2 and below) that has been inaccessible by the large experiments using liquefied noble gas (Ar / Xe) detectors.

The PAC is pleased to note that EDELWEISS-RICOCHET is focused at addressing intriguing problems of modern physics, has produced world-leading results and maintains strong competitive capabilities.

Recommendation. The PAC recommends continuation of the EDELWEISS research programme on the direct search for dark matter particles and its expansion to the RICOCHET project for the precision measurement of CEνNS in 2022–2024 with ranking A.

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