Referee Report to the 53rd Nuclear Physics PAC meeting Jan. 22, 2021 of JINR

Theme "Non-Accelerator Neutrino Physics and Astrophysics"

This theme comprises seven independent large scientific projects and experiments of the DLNP lab in the field of non-Accelerator Neutrino Physics and Astrophysics, that have all been separately reviewed and recommended in recent PAC meetings. Therefore, the progress as reported since the last reviews will be discussed below.

1) Project SuperNEMO (2β-decay processes of ^{82}Se with SuperNEMO detector)

Using the experience from the successful NEMO-2 and NEMO-3 experiments, the JINR team has made substantial contributions toward the realization of the **"SuperNEMO Demonstrator"** in the Mondane underground laboratory (LSM, France). It will be the first module (out of 20) of SuperNEMO to search for (0ν2β)-decays of ^{82}Se using a technique based on tracking and calorimetry. This technique allows full kinematic reconstruction of 2β events with strong suppression of backgrounds. The main JINR contributions were creation and tests of scintillators (calorimeter), tracker cells, radon control, upgrading and purification of the ^{82}Se source, etc. Completion of the "Demonstrator" including iron shielding is planned by the end of 2022. Using 7 kg of the ^{82}Se isotope, the goal after 2.5 years of production is to reach a lower limit $T(0\nu\beta\beta)_{1/2} > 6x10^{24}$ years.

Unfortunately, a **detailed report testifying the progress made since 2017 is missing and should be submitted**. If the Dubna team can make a convincing case of their future involvement, I strongly recommend that JINR continues with full support of the SuperNEMO project.

2) Project GERDA "LEGEND" (Search for (0ν2β)-decay of ^{76}Ge)

"LEGEND" is the successor experiment of Gerda, a search for the (0ν2β)-decay of ^{76}Ge in the Gran Sasso laboratory (LNGS, Italy). Using ^{76}Ge-enriched semiconducting detectors embedded in a liquid Ar tank and further shielding and veto counters, this device has100% sensitivity for (0ν2β)-decays with excellent energy resolution and background suppression. Gerda has reached a lower limit of the lifetime for ^{76}Ge of $T(0\nu\beta\beta)_{1/2} > 1.8.x10^{26}$ years with no background in the sensitive energy region. This result represents the highest sensitivity reached so far of all 0νββ searches!

LEGEND-200 is an upgrade of Gerda with many improvements in sensitivity and background reduction to be realized in 2021/22. With 200 kg of the ^{76}Ge isotope (up from 31 kg of Gerda) the sensitivity will be pushed to $T(0\nu\beta\beta)_{1/2} > 10^{27}$ years. The ultimate goal will be LEGND-1000 using 1 ton of ^{76}Ge aiming for a unprecedented sensitivity of $>10^{28}$ years.

The GERDA "LEGEND" project has greatly demonstrated its frontier performance in (0νββ) decay searches and promises to keep the lead in coming years with the planned upgrades. Therefore I recommend to continue supporting it with highest priority.

3) Project νGEN (Investigation of ν properties with low background Ge spectrometer νGEN)

The νGEN project is a reactor experiment investigating fundamental neutrino properties (search for coherent ν-N scattering, ν magnetic moment) at low energies using high-purity Germanium detectors. It is located 10 m underneath the Kalinin nuclear reactor "block3" employing the worldwide highest anti-neutrino flux available for experiments ($>5x10^{13}\nu/cm^2/s$). The predecessor experiment (Gemma-I) has reached the lowest upper limit of ν magnetic moment of $< 2.9x10^{-11}\ \mu_B$. The new setup will run with

a number of improvements (more Ge detectors, better resolutions and shieldings) yielding ~5 fold improvements in sensitivity.

νGEN is a high class JINR project on the frontier of neutrino physics and should be supported with highest priority.

4) Project DANSS (Detector for reactor anti-ν based on solidstate plastic scintillators)

The DANSS spectrometer is a detector for reactor neutrino searching for oscillations into sterile neutrinos, located at the Kalinin powerplant, reactor "block4". The sensitive volume consists of ~1 m^3 of plastic scintillation counters of high granularity registering ~5000 anti-neutrinos per day. The present issue is that one experiment (NEUTRINO-4 in Gatchina) has reported 2005 such neutrino oscillations while all other of the worlds leading experiments including DANSS did not observe any oscillations, and instead present strong exclusion plots.

The plans of DANSS is in 2022-24 to launch an upgraded DANSS-2 detector with much improved energy resolution being more sensitive to the region of the NEUTRINO-4 experiment.

The existence of neutrino oscillations to sterile neutrinos is an extremely important physics question and must be clarified in future more precise experiments. Therefore I strongly recommended that the DANSS-2 development is continued and fully supported by the JINR lab.

5) Project EDELWEISS/RICOCHET (direct dark matter search and precision study of coherent elastic neutrino-nucleus scattering with new cryogenic detectors)

The Edelweiss project, located at LSM (Mondane, France), is a search for dark matter in the low energy sector, i.e. for weak interacting massive particles (WIMPS) producing tiny eV signals. The detectors are Ge mono-crystals operated at cryogenic conditions of a few mK using bolometer readout. The Ricochet experiment, to be performed in the vicinity of the Grenoble nuclear reactor (ILL, France), searches for the same kind of ultra-low energy signals produced from reactor neutrinos by coherent elastic nucleus scattering. The R&D is done in joint collaboration for both projects.

In a 3-years program, new detectors (mass ~1kg) will be developed for Edelweiss and brought to operation with greatly improved sensitivity, energy threshold ~10 eV, better background reduction, etc.

Based on the very successful recent results of dark matter search, I strongly recommend continuation of the Edelweiss/Ricochet projects with full support from the JINR lab.

6) BAIKAL-GVD (Deep underwater muon and neutrino detector on Lake Baikal)

The.Baikal-GVD (Giga Volume Detector) is a ultra-large under-water detector, consisting on arrays of strings going 1275 m down in the Lake Baikal on which optical modules (large PMTs to view Cerenkov radiation from charged particles produced by the neutrino interactions) are arranged every 15 meters. This detector is designed to study highest energy neutrinos originating from the most violent processes in the universe. It is one out of three such massive neutrino detectors in the world, the other two being IceCube on the south pole and KM3NeT in construction in the Mediterraneum. Presently the Baikal-GVD runs 7 clusters, each comprising 8 strings, 192 optical modules in total, comprising an effective detection volume of 0.35 km^3.

The Baikal-GVD project is one of the great achievements of JINR. I strongly recommend – now in full production phase – that it is continued to be fully supported by the JINR Laboratory.

7) MONUMENT (Muon Ordinary capture for Nuclear Matrix elements in ββ decays)

The Monument project was just reviewed in June 2020 by the NP-PAC and received full support and approval for the proposed 3-years program. Using a large Germanium detector array located at the PSI muon beam (Villigen, Switzerland), it investigates ordinary muon capture on nuclei of interest for double beta decay experiments, to obtain relevant information on level schemes, transition rates and nuclear matrix elements. This data is of decisive importance for the understanding and interpretation of the ongoing ββ-decay experiments. The Dubna team has already performed a successful data run in 2019, in collaboration with the PSI mu-X experiment.

I strongly recommend continuation of the full support of the Monument project by the JINR lab.

GENERAL CONCLUSION

All seven projects about Non-Accelerator Neutrino Physics and Astrophysics are absolutely high-rated projects on the frontier of the science of Nuclear and Particle Physics. They have demonstrated excellent progress in the past years and propose very promising improvements and upgrades, mostly already underway. Therefore I recommend continuation and full support of the theme "Non-Accelerator Neutrino Physics and Astrophysics" by the JINR Lab for the next 3 years.

One special comment: the SuperNEMO project should also submit a progress report about the last 3 years as all the others have done!

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