SuperNEMO project   O.Kochetov

QUESTIONNAIRE

1. Goals of the experiment:

1a. Give a short description of the goals of the experiment.

The SuperNEMO project is aimed to search neutrinoless double beta decay ($0\nu\beta\beta$), which would be an indication of new fundamental physics beyond the Standard Model, such as the nature of neutrino (either Dirac or Majorana), the absolute neutrino mass scale, and neutrino hierarchy. Observation of $0\nu\beta\beta$ would also help to resolve the topical puzzles of fundamental physics: CP violation, Leptogenesys, GUTs.

SuperNEMO is a next generation experiment based on the same successful NEMO-3 tracking and calorimetric technology. The goal of SuperNEMO is to reach a sensitivity on the Majorana effective neutrino mass of 50-100 meV with an exposure of 500 kg.y by using ~100 kg of enriched ^{82}Se.

The main goal of the Demonstrator- the first of 20 modules of SuperNEMO, is to demonstrate feasibility of mass production, to measure backgrounds especially from radon emanation, to finalise the detector design. With 7 kg of ^{82}Se isotope the Demonstrator is aimed to reach the $0\nu\beta\beta$-decay half-life sensitivity $T(0\nu)_{1/2} > 6 \cdot 10^{24}$ yr in 2.5 years.

1b. Explain what the project adds to the international scenario.

The SuperNEMO brings the unique detection technique for the $\beta\beta$-community. It is based on tracking and calorimeter measurements, and allows the reconstruction of the whole event topology with the full kinematics of detected particles, including individual energies and emission angles, resulting in a strong reduction of the background and the possibility to disentangle different $\beta\beta$-decay mechanisms.

Although ^{82}Se is the baseline isotope, other isotopes, e.g., ^{150}Nd, ^{96}Zr, ^{48}Ca are envisioned. A background-free search for an isotope with a high $Q_{\beta\beta}$ and favorable kinematical factors may reach high sensitivities to effective neutrino mass for exposures of an isotopic mass much smaller than a ton scale. For example, a 200 kg sample of ^{48}Ca, in a no-background five-year exposure can be sensitive to a substantial portion of the inverted hierarchy mass region. The challenge there includes new enrichment techniques for these difficult to enrich isotopes like ^{48}Ca, ^{96}Zr, and ^{150}Nd. The SuperNEMO offers wide flexibility to select a best suitable isotope in the future searches.

The NEMO-3/SuperNEMO is unique "$\beta\beta$-factory", which has provided the world's best (at the time of publication) $\beta\beta$-decay measurements of seven isotopes: ^{100}Mo, ^{82}Se, ^{116}Cd, ^{150}Nd, ^{48}Ca, ^{96}Zr, and ^{130}Te. This is an important contribution to the improvement of our theoretical knowledge of the bb-mechanisms (calculations of NME of $\beta\beta$-decay processes).

2. Contributions of the JINR group:

2a. JINR has made a decisive contribution to the creation of the Demonstrator module of the SuperNEMO:

1. R&D and production of 720 plastic scintillator blocks for the Demonstrator calorimeter (in cooperation with the University of Prague).
2. R&D and manufacturing of 60 optical modules for the VETO system (scintillator + PMT 5" R6594 HAMAMATSU).
3. Have given 100 PMT 8"R5912-03 HAMAMATSU for the calorimeter.

4. Provided 7 crates for the electronics of the calorimeter.
5. Prepared 3.5 kg of purified enriched ^{82}Se for the production of foils-sources.
6. A unique ^{82}Se purification technique has been developed and implemented. A clean room has been built, and 3.5 kg of ^{82}Se has been purified.
7. Manufacturing of signal and HV cables for the tracker.
8. Development, creation, and maintenance of equipment for low-background measurements at LSM: germanium, radon, and neutron detectors (including shielding).
9. Iron passive shielding against gammas is now being developed and will be created.
10. Essential contribution in software development, simulations, data base creation, and data analysis.

2b. Give a list of the responsibilities of JINR group members.

The Dubna team has 25 yr experience of work in the NEMO2/NEMO-3/SuperNEMO projects. Our main responsibilities:

1. Radiochemical purification of isotopes and production of radioactive mono-isotopes.
2. Calorimeter and VETO R&D and productions.
3. Software development, simulations, and data analysis.
4. Manufacturing of signal and HV cables for the tracker, cabling, testing and tuning.
5. Acquisition, creation and maintenance of equipment for low-background measurements: germanium, radon, neutron detectors in LSM.

3. Plans

1. 2018 - completion of the Demonstrator assembly. The launch of the Demonstrator without neutron shielding.
2. 2019 - the calibration of the Demonstrator. The creation of neutron shield of the Demonstrator. The calibration and run of data collection in the full configuration of the Demonstrator.
3. 2020-2021 - data taking, data analysis, background assessment, control of backgrounds, publication of first results.
4. During the whole period - the continuation of the R&D program on the methods of enrichment of other isotopes: ^{150}Nd, ^{96}Zr, ^{48}Ca. Improvement of the cleaning procedure for ^{82}Se. Further development of PS production technique.

4. Publications:

1. R. Arnold et al., "The BiPo detector for the measurement of ultra low natural radioactivities of thin materials", submitted JINST (2017) 12 P06002. JINR contribution: production of PS for the BiPO detector.

2. Arnold, R., Augier, C., Barabash, A.S. et al. Final results on Se-82 double beta decay to the ground state of Kr-82 from the NEMO-3 experiment Eur. Phys. J. C (2018) 78: 821. https://doi.org/10.1140/epjc/s10052-018-6295-x JINR contribution: V.Tretyak: head of the data analysis group and the main author of analysis.

3. R. Arnold, O. Kochetov et al., "Measurement of the double-beta decay half-life and search for the neutrinoless double-beta decay of Ca-48 with NEMO-3 detector", Phys. Rev. D 93, (2016) 112008-1 – 112008-9. JINR contribution: V.Tretyak: the head of the data analysis group.

4. R. Arnold, J. Kochetov et al., "Measurement of the double-beta decay half-life of Nd-150 and a search for neutrinoless double-beta decay processes with the full exposure from the NEMO-3 detector", Phys. Rev. D 94 (2016) 072003. JINR contribution: V.Tretyak: the head of the data analysis group.

5. R. Arnold, O. Kochetov et al., "Measurement of the Double-Beta Decay Half-Life and Search for the Neutrinoless Double-Beta Decay of Cd-116 with the NEMO-3 Detector", Phys. Rev. D 95 (2017) 012007, arXiv: 1610.03226. JINR contribution: V.Tretyak: the head of the data analysis group.

6. R. Arnold, O. Kochetov et al. from NEMO-3 Collaboration, "Search for neutrinoless quadrupole-b decay of the Nd-150 with the NEMO-3 detector" Phys. Rev. Lett. 119 (2017) 041801. JINR contribution: V.Tretyak: the head of the data analysis group.

8. A.S. Barabash, O.Kochetov et al., "Calorimeter development for the SuperNEMO double beta decay experiment" Nuclear Instruments & Methods in Physics Research A . – 2017 Vol.868 (2017) p.98-108. JINR contribution: R&D of calorimeter.

9. V. Brudanin et al., "Environmental radionuclides as contaminants of HPGe gamma-ray spectrometers: Monte Carlo simulations for Modane underground laboratory" May 2018, Journal of Invironmental Radioactivity. JINR contribution: HPGe detector OBELIX used as main detector for ultra low background studies.

Total number of published papers in 2016-2018: 20.

5. PhD theses:

1. Genko Marinov. Production, separation and application of radioactive isotopes in the study of compounds of rare earth element. Defended at Sofia University (Bulgaria) in October 2018.

The work was been done at the radiochemical laboratory of DLNP. The results are important for the purification of neodymium and zirconium - potential promising candidates for the measurement of double beta decay with the SuperNEMO method.

2. Rakhimov A.V. Radiochemical aspects of separation, conditioning and analysis of the compounds as exemplified by large area thin samples of highly refined selenium-82 for the low background studies. Will be defended in 2019 at the Department of Radiochemistry of Moscow State University.

The work has been fulfilled at the radiochemical laboratory of DLNP. A unique purification procedure for selenium has been developed. Two kilograms of enriched selenium purified by this method were used to make source films of the Demonstrator of the SuperNEMO.

6. Talks:

1. V. Tretyak, on behalf of the NEMO3 collaboration. Latest Results of NEMO-3: ^{100}Mo $2\nu2\beta$-decay measurement and search for Majoron and exotic processes. The XXVIII International Conference on Neutrino Physics and Astrophysics (Neutrino 2018), 4-9 June 2018, Heidelberg, Germany.

7. Group size, composition and budget.

7a. Present in a Table the list of JINR personnel involved in the project, including name, and FTE. Mention the total number of people in the collaboration.

N	Person	Status	Subjects	FTE
1	O.I Kochetov	Project Leader	calorimeter	0.9
2	Yu.A.Shitov	Deputy Leader	software, data analysis	0.5
3	V.B.Brudanin	Participant	calorimeter	0.1
4	V.I. Tretyak	Participant	Head of software and data analysis group	0.9
5	V.G.Egorov	Participant	calorimeter, data analysis	0.1
6	A.A. Smolnikov	Participant	calorimeter, data analysis	0.2

7	A.A. Klimenko	Participant	software, data analysis	0.2
8	D.V. Karaivanov	Participant	radiochemistry, ^{82}Se-purification, sources	0.35
9	A.V. Rahimov	Participant	radiochemistry, ^{82}Se purification, sources	0.35
10	D.V. Filosofov	Participant	radiochemistry, ^{82}Se purification, sources	0.3
11	N.A. Mirzaev	Participant	radiochemistry, ^{82}Se purification, sources	0.4
12	G.Marinov	Participant	radiochemistry, ^{82}Se purification, sources	0.5
13	A.V. Salamatin	Participant	electronics,cables	0.3
14	V.V. Timkin	Participant	calorimeter, VETO system and cables	0.9
15	I.B. Nemchenok	Participant	PS production, calorimeter and VETO system	0.2
16	I.I. Kamnev	Participant	PS production, calorimeter and VETO system	0.3
17	O.I. Vagina	Participant	PS production, calorimeter and VETO system	0.3
In total				**5.2**

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

Essential changes are not expected.

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…)

List of parts and devices; Resources; Financial sources	Cost of parts (K US$), resources needs	Allocation of resources and money		
		1st year	2nd year	3rd year

Main parts and equipment	1. Materials for a calorimeter (styrene, aluminum, P-terphenyl, POPOP) 2. Spectroscopic electronics for test stands of PS&PMTs 3. Borated polystyrene for neutron shielding of the Demonstrator 4. Materials&equipment for Demonstrator maintenance under JINR responsibility (2 Radon detectors, HPGe spectrometer,) and carrying out calibrations, including creation of calibration sources. Radiochemical equipment.		24 10 40 45	8 10 30 15	8 0 10 15	8 0 0 15
	Total		**119**	**63**	**33**	**23**
Resources	Norm-hours	JINR workshop	0	0	0	0
		DLNP workshop	1800	600	600	600
Financial sources	budget	Budget spending	119	63	33	23
	Off-budget sources	Grants; Other sources (these funds are not currently guaranteed)	*30*	*10*	*10*	*10*

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

JINR computing resources are not used.