**GEMMA/(vGEN) project (within 1100)**

## 1. Goals of the experiment:

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

The GEMMA project is aimed to investigate fundamental properties of neutrino using enormous neutrino flux at the close vicinity of the reactor core of Kalinin Nuclear Power Plant (KNPP). The investigations are focused on searches of Magnetic Moment of Neutrino (MMN) and coherent elastic neutrino-nucleus scattering (CEvNS). The first phase of the project (GEMMA-I) set up the world best upper limit for the Magnetic Moment of Neutrino (MMN) of $\mu_{\nu e} < 2.9 \cdot 10^{-11} \mu_B$ (90% CL). For GEMMA-III experimental sensitivity to MMN will be improved to the level of $(5\text{-}9) \cdot 10^{-12}$ $\mu_B$ after several years of data taking. The search for the coherent scattering of the neutrino (CEvNS) from the reactor is one of the primary goals within the GEMMA/vGEN projects. This process has never been observed for neutrino with fully satisfied requirements of coherency.

The GEMMA-III experiment set under the reactor #3 of KNPP at a distance of about 10 m from the center of the reactor‘s core under an enormous antineutrino flux of more than $5 \cdot 10^{13}$ ν/(cm$^2$·s). GEMMA-III uses unique HPGe detectors (5.5 kg in total, 4 detectors) with an ultimate resolution of about 80 eV (FWHM). Ultimate energy threshold of such detectors allow exploring the energy region from about 200 eV, i.e. to detect for first time coherent neutrino-nuclear scattering at the energy region of full coherency (νGeN stage of the experiment). Reliability of the results will be achieved thanks to: HPGe detectors with well known energy response, low-radioactive cryostat tested at LSM underground laboratory, radioactive-less materials selected for the passive shield of the setup, highly-efficient active veto systems, modern acquisition chain providing pulse shape discrimination of signals from the noise. For confirmation of coherent scattering signal the experiment will use differential methods of measurements. Energy spectra received with working ("on") and stopped ("off") reactor will be compared. Apart from this, in long periods of working reactor the measurements will be conducted at several points located at different distances (from 10 to 12.5 m) from the reactor (the setup is placed on a special lifting mechanism). This will provide substantial data about coherent neutrino signal and the background.

We expect to have first results of measurements with GEMMA-III at first half of 2019. At once first detection of the coherent scattering will be accomplished the detectors will be applied for further studying of the process in details.

Further development will be connected with new HPGe detectors with increased mass (up to 10 kg in total, with increased mass of single detector in order to improve the self shielding from the background).

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

Investigation of neutrino properties is a hot topic in modern physics. With the progress of the experimental techniques, it became possible to use very low energy threshold detectors for search of the weak signals from the neutrino scattering. Last year COHERENT experiment claimed about observation of CEvNS from accelerator with the CsI detector. The result was obtained with a mixture of rather high energy neutrino of different types, around the coherency limit. The result has to be confirmed in independent experiment. Investigations with the reactor neutrino are performed with low energy neutrinos satisfying requirement of coherency. Many experiments are trying to accomplish such kind of investigations. Different experimental technique used to detect CEvNS and it is very important for complementarity of the research as well. Many experiments are currently are running or preparing their setups: CONUS, MINER, Ricochet, CONNIE, NU-CLEUS and others. The main advantage of vGEN/GEMMA-III experiment is the experimental location. The experimental setup can be placed under very high intense neutrino flux of more than $5 \cdot 10^{13}$ ν/(cm$^2$·s) – this is the best value among the other experiments. Moreover, it is located under the reactor, surrounded by constructive materials of reactor building, equivalent to about 50 m w.e. overburden. Lifting mechanism of the experimental setup allows change the neutrino flux thus reduce systematic uncertainties of background. Search at KNPP with germanium detectors may open a way to search New Physics beyond the Standard Model via observation of MMN or precision measurements of CEvNS to search of non-standard neutrino interactions. Since it is going to be the smallest detector able to detect neutrino from the reactor, it opens a way to different applications, like reactor monitoring.

**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.**

The JINR group has leading role in the GEMMA-III project. JINR contributions covers all parts of experiment including all hardware, software development and physics analyses. The experimental setup is building by JINR resources and manpower. The custom-made unique HPGe low threshold detectors/low background cryostat are produced in cooperation between JINR and CANBERRA. Facilities of Modane underground laboratory (LSM, France), thanks to JOULE agreement between LSM and JINR, were used for low radioactive material selection and for tests of detectors.

List of main components of the GEMMA-III setup is (all belongs to JINR):

HPGe detectors with energy threshold 200 eV, total mass 5.5 kg;
Low radioactive cryostats;
Low radioactive materials of the γ- shield, production of the shield;
Neutron shield;
Active anti μ-, anti γ- veto shields;
Lifting mechanism with platform for the setup;
Calibration system;
Supplementary detectors for control γ- and neutron backgrounds;
Modern acquisition chains (HV supplies, amplification, racks, ADCs, computers) for the main detectors, for the veto systems and for supplementary detectors.

JINR group is fully responsible for MC, acquisition software and for data analysis.

**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.**

The project leader is V.B. Brudanin (JINR);

The deputy leaders are also from JINR: A.V.Lubashevskiy (onsite management, HPGe detectors, MC, analysis) and E.A.Yakushev (background, low radioactive materials, supplementary and veto detectors).

**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.**

At the present time the experiment is in the commissioning phase at KNPP. Neutrino data taking will be accomplished with extensive calibrations, background measurements and supplementary measurements. We expect to have first results of such measurements in 2019. The primary goal is to detect the CEvNS from the reactor. Long stable data taking is required in order to perform precision measurements of CEvNS and searches for MMN.

In the same time our group will continue R&D of new detectors with further decreasing of the energy threshold to region at about 100 eV with simultaneous increasing of their mass in order to have improved background index due to more effective self shielding. With new detectors the total mass of the HPGe at the setup will be increased to 10 kg.

**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.**

The detail description of vGEN experiment was published in V.Belov et al, "The νGeN experiment at the Kalinin Nuclear Power Plant", JINST 10 (2015) no.12, P12011.

New low threshold detectors for GEMMA-III were obtained and tested in 2018. Measurements of backgrounds, materials' selection, building of shields, building of veto systems were accomplished during previous period, thus there were no refereed publications concerning GEMMA-III. Our priority was to build the experimental setup as soon as possible and start the measurements. Publications with the description of the current experimental setup is under preparation. JINR scientists have major contribution in all parts of the vGEN/GEMMA-III experiment including preparation of the papers. The corresponding authors are from 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.**

List of PhD theses expected to be completed in 2019:

M.Shirchenko, "Experimental investigation of electromagnetic neutrino properties at low energies by precision nuclear spectroscopy".

D.Medvedev, "The results of searching for neutrino magnetic moment in GEMMA experiment".

**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.**

A.V. Lubashevskiy, "Experimental search for the coherent neutrino scattering with the vGEN experiment", ISSP 2017, Erice, Italy

**6b. Give a similar list for parallel talks.**

A.V. Lubashevskiy, "Investigation of neutrino properties with the vGEN spectrometer", VLVnT-2018, Dubna, Russia.

A.V.Lubashevskiy, "Status of vGEN project", ICSSNP-2017, Nalchik, Russia.

D.V. Medvedev, "Study of neutrino properties with Ge detectors on KNPP", ICSSNP-2017, Nalchik, Russia.

S.V.Rozov, "Experiment for Detection Coherent Neutrino – Ge Nucleus Elastic Scattering", AYSS-2016, Dubna, Russia

D. Medvedev, "Searching for neutrino magnetic moment and coherent scattering in GEMMA and νGeN", AYSS 2016, Alushta, Russia, 2016

**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.**

vGEN/GEMMA-III is a small collaboration mostly consist of JINR staff, with some participations of people from other Russian institutes and Czech Republic.

| Name | Category | Responsibilities | Time that each participant will give to the work under the Project in relation to its Full Time Equivalent(FTE) |
|---|---|---|---|
| V. Brudanin | Head of department | Administrative work, project management | 0.2 |
| V. Belov | Junior researcher | Muon veto, MC | 0.2 |
| V. Egorov | Head of sector | Management, constructions, data analysis | 0.3 |
| M. Fomina | Junior researcher | Muon veto, MC | 0.3 |
| A. Lubashevskiy | Senior Researcher | Data analysis, MC, commissioning and administrative work | 0.5 |
| D. Medvedev | Reseacher | Data analysis, MC | 1.0 |
| D. Ponomarev | Engineer | Constructions, detectors building, testing. Experiment running. | 1.0 |
| M. Shirchenko | Reseacher | Experiment running. Data analysis | 0.3 |
| V.Sandukovsky | Head of sector | Detector configuration, constructions | 0.5 |
| S. Rozov | Engineer | Detector building, testing, calibration, running. | 0.5 |

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| I. Rozova | Engineer | Data analysis, constructions | 1.0 |
| I. Zhitnikov | Junior researcher | Experiment running, data analysis | 0.2 |
| E. Yakushev | Head of sector | Building, commissioning, running, data analysis | 0.3 |
| D. Zinatulina | Reseacher | Muon veto, MC | 0.2 |
| Z.Kalaninova | Reseacher | MC | 0.8 |
| Total FTE (Engineers): 2.5, Total FTE (Scientific staff): 4.7, Total FTE: 7.2 | | | |

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

No significant changes are expected within the project team at the moment. In the same time technical /engineer staff can be increased from the theme resources at once requested. There is also share in man power between DANSS and GEMMA projects at KNPP, as well between EDELWEISS and GEMMA projects during activities at the LSM underground laboratory.

**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…)**

The GEMMA-III project is a part of the scientific theme 1100 “Non-accelerator neutrino physics and astrophysics” at JINR which is devoted to search and investigation of rear processes by means of nuclear physics methods. GEMMA-III-only requested resources are reflected into the form No.29 of the written project (PAC-NP, January 2018) - duplicated on the next pages.

**Estimated expenditures for the Project** GEMMA-III, Investigations of neutrino properties with the low-background germanium spectrometer GEMMA-III

| # | Designation for outlays | Total cost | 1 year | 2 year | 3 year |
|---|---|---|---|---|---|
| Direct expenses for the project | | | | | |

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|---|---|---|---|---|---|
| 1. | Networking | 6.0K US$ | 2.0 | 2.0 | 2.0 |
| 2. | DLNP workshop | 600 norm-hours | 200 | 200 | 200 |
| 3. | Materials | 40.0K US$ | 25.0 | 10.0 | 5.0 |
| 4. | Equipment | 175.0K US$ | 145.0 | 30.0 | 0.0 |
| 5. | Expenses for R&D on a contract base | 6.0K US$ | 2.0 | 2.0 | 2.0 |
| 6. | Travel expenses,<br>including | 60.0K US$ | 20.0 | 20.0 | 20.0 |
| | а) to nonrouble zone countries | | 5.0 | 5 | |
| | б) to cities of rouble zone countries | | 15.0 | 15.0 | 20.0 |
| | **Total** | **287.0K US$** | **194.0KUS$** | **64.0KUS$** | **29.0K US$** |

7d. At the moment there is no need to use JINR computing resources for the project.