EDELWEISS-LT project

1. Goals of the experiment:

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

The project is continuation of the EDELWEISS scientific program conducting by JINR in the international collaboration. Direct search for Dark Matter (DM) particles is the fundamental scientific problem addressed by the EDELWEISS. It searches for DM using an array of cryogenic germanium bolometers able to identify events consisting of WIMP-induced nuclear recoils. After the completion of EDELWEISS-III phase of the experiment, the experimental program is moving to EDELWEISS-LT phase, with aims of investigation of DM particles in forms of "light" WIMPs with masses in the 0.1 to 6 GeV/c^2 range, down to cross-sections where the search will be limited by the irreducible background from the coherent nuclear scattering of solar neutrinos. At 1 GeV/c^2 and below, the neutrino floor corresponds to a cross-section of 7×10^{-45} cm^2 (~2×10^{-45} cm^2 at 0.1 GeV/c^2). In the absence of background, the required sensitivity to reach this neutrino floor could be obtained with an exposure of 20 kg.y of a detector with a 10 eV resolution for nuclear recoils. Such an exposure requires an array of cryogenic detectors, each with typical mass between 100 g and 1 kg. However, the reach below 1 GeV/c^2 of all present and future experiments is limited by non-NR backgrounds, and it is therefore will be crucial to improve the discrimination performance at low energy. Thus, in general, the collaboration has the aim to develop new detectors/low background setup that will allow explore DM search in the ranges not accessible by other techniques. The experiment is not limits itself by light WIMP search, presence of signals from other DM particles will be investigated (Axion Like Particles).

In parallel with main goal of the experiment targeted by the collaboration, the JINR EDELWEISS group has an own agenda connected with using of the EDELWEISS infrastructure to R&D of classical semiconductor detectors with ultra-low energy thresholds and for selection of less-radioactive materials. This is one of the bases for current "home" experiments, as GEMMA/νGeN, as well is the base for further developments.

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

Determination of properties of DM particles is one of the main task for modern physics, therefore there is an intense experimental activity around the globe on the DM particle direct detection since many years. In the present time there is an increasing gain of interest for the search of low-mass WIMPs and other DM candidates arising on the one hand from experiments (no observation yet of SUSY at the LHC, no DM detection after huge 1 ton × year exposure with liquid Xe) and on the other hand from new theoretical approaches favouring lighter candidates. As an example, asymmetric DM models linking the relic density to the baryon asymmetry predict DM particles with masses of a few GeV/c^2. A wide region of the parameter space (σ_{SI} m_W) giving spin-independent WIMP-nucleon cross-sections (σ_{SI}) as a function of WIMP mass (m_W) is thus yet to be explored at such low WIMP masses. With the fact that liquid xenon experiments stand now as leaders in high-mass WIMP searches (10 GeV/c^2 to 1 TeV/c^2), a division of work is taking shape in the hunt for DM particles: an exploration of the high-mass region led by experiments with liquid scintillators, and light WIMP models to be tested by cryogenic detector experiments. In this new context, the EDELWEISS experiment originally designed for the search of WIMPs of O(100 GeV/c^2) has undergone a redirection of its strategy to optimization of its detectors for low-mass (light) WIMP searches (EDELWEISS-LT). During EDELWEISS-III phase of the experiment using 800-g Ge detectors with discrimination its LSM-based setup had the largest mass of cryogenic Ge detectors ever built (20 kg). The results confirmed the power of the discrimination based on the double measurement of ionization and phonon signals, for 4 to 30-GeV/c^2 scale WIMP masses. For example, the positive hints for DM detection reported by some others experiments were directly verified with much better sensitivity. It is important that the achieved by EDELWEISS-III sensitivity completely covered region of positive CoGeNT results obtained on the same nuclear (Ge).

Complicity of experimental techniques for direct DM detection combined with model-dependent interpretation of results makes multi-target/multi experimental technique approach as the only reliable way for DM detection/investigation. With this in mind the development of modern Ge-based DM search experiment EDELWEISS-LT has highly valuable importance for direct DM search.

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.

JINR made hardware:

- Highly sensitive radon detection system to continuous control of air at proximity to the EDELWEISS cryostat + data analysis + database data transfer;
- Movable radon detector that is mainly used for control air quality of the radon-free air factory.
- Two low background thermal neutron detectors based on He-3 counters + development of the low noise data acquisition chain + data analysis. These neutron detectors were used for accurate investigation of neutron field and its stability in the LSM underground laboratory as well inside of the EDELWEISS shields.
- Fast neutron detection setup based on 4 He-3 counters and PE moderator + development of the low noise data acquisition chain + data analysis.
- New thermal neutron detection system based on iodine containing scintillators. Development of the method, all components of the detector, data analysis.
- Low background alpha spectrometer with exchangeable silicon PIN alpha detector of high area. Work include tests of PIN diodes, measurements, data analysis.
- Elements of passive lead shield for EDELWEISS R&D cryostat at IPNL.
- Two HPGe spectrometers for selection of less-radioactive materials (this is part of LSM-JINR common infrastructure that is also used by other experiments with JINR participation).
- Low threshold HPGe detectors for DM search (EDWIGE branch of the EDELWEISS).

Software: Being experts in low-energy electron spectroscopy our group developed low energy particle generator including all atomic processes in low energies (Auger, Coster Kronig transitions, X-rays) crucially important for background model at DM search region.

We are fully responsible for data acquisition software for radon/neutron/alpha detectors as well for data analysis from those detectors.

We are fully responsible for data analysis accumulated with the EDWIGE (EDELWEISS-I shield HPGe detectors R&D) branch of the EDELWEISS.

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.

E. Yakushev is permanent member of the EDELWEISS executive/institute board.

E. Yakushev is responsible for EDWIGE (EDELWEISS-I shield HPGe detectors R&D) branch of the EDELWEISS.

S. Rozov is permanently responsible for all EDELWEISS neutron monitoring.

JINR group is responsible for low-radon level (one of the main part of low-radioactivity WP) at the experiment.

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.

As the part of collaboration with less than 50 members (very small by modern standards) the Dubna team has to participate and make commitment to all stages of the EDELWEISS project:

- Assembly and commissioning of experimental setup;
- Data taking (include daily routine procedures, as well as regular and special calibration runs);
- Low background study and further development of methods of neutron and radon detection; screening of materials on their radioactive contamination; In JINR we also will develop equipment for radon-emanation study; In cooperation with radiochemistry sector new less-radioactive components will be developed (as, for example, soldering and flux).
- Development of new detectors;
- Detector simulations, data acquisition (digital filtering) and data analysis;
- R&D of new low energy threshold HPGe detectors. To do physics with EDWIGE part of the EDELWEISS we will have to build improved passive and new active shields, new acquisition PSD system, provide new low energy threshold detectors.

More detailed description of the activities is presented at the written project (PAC-NP in January 2018).

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 EDELWEISS is collaboration with less than 50 signatures of the papers. Therefore, each of EDELWEISS papers is result of every member of the collaboration.

JINR group is involved in all stages of the experiment: setup assembly and commissioning, modeling, data taking, calibrations, analysis, publication.

E. Armengaud et al, (EDELWEISS collaboration), "Searches for electron interactions induced by new physics in the EDELWEISS-III germanium bolometers", Physical Review D 98 (8), **2018**, 082004;

Q Arnaud et al, (EDELWEISS collaboration), "Optimizing EDELWEISS detectors for low-mass WIMP searches", Physical Review D 97 (2), **2018**, 022003;

E Armengaud, et al (EDELWEISS collaboration), "Measurement of the cosmogenic activation of germanium detectors in EDELWEISS-III", Astroparticle Physics, 91, **2017**, 51-64;

E Armengaud, et al (EDELWEISS collaboration) "Performance of the EDELWEISS-III experiment for direct dark matter searches", Journal of Instrumentation, 12, 08, **2017**, P08010;

L Hehn, et al (EDELWEISS collaboration) "Improved EDELWEISS-III sensitivity for low-mass WIMPs using a profile likelihood approach", The European Physical Journal C 76 (10), **2016**, 548;

E Armengaud, et al (EDELWEISS collaboration) "Constraints on low-mass WIMPs from the EDELWEISS-III dark matter search", **2016**, Journal of Cosmology and Astroparticle Physics **2016** (05), 019.

Together with above EDELWEISS papers, due to synergy between EDELWEISS and CUPID-experiment directed to neutrino-less double beta decay search, there are 3 more publications (not listed here) in 2017-2018 signed by the EDELWEISS collaboration.

There are also publications based on researches directly connected with our responsibilities in collaboration. But, since these R&Ds performed independently from EDELWEISS, the papers below are not signed by other EDELWEISS members.

E. Yakushev, S. Rozov, A. Drokhlyansky, D. Filosofov, Z. Kalaninova, V. Timkin, D. Ponomarev, "Sensitive neutron detection method using delayed coincidence transitions in existing iodine-containing detectors", NIM A, **2017**, 848, 162-165;

V. Brudanin, VG Egorov, R Hodák, AA Klimenko, P Loaiza, F Mamedov, F Piquemal, E Rukhadze, N Rukhadze, I Štekl, Yu A Shitov, G Warot, EA Yakushev, M Zampaolo, "Development of the ultra-low background HPGe spectrometer OBELIX at Modane underground laboratory", Journal of Instrumentation 12 (02), P02004, **2017**;

N. Fedyunina, Fedotov P.S., Filosofov D.V., Yakushev E.A. "ICP-MS determination of ultralow contents of uranium and thorium in antique lead after their isolation by countercurrent chromatography (liquid-chromatography with a free stationary phase)." Industrial laboratory. Diagnostics of materials. **2018**, 84 (4), 12-15;

P. Fedotov, N. Fedyunina, D. Filosofov, E. Yakushev, G. Warot, "A novel combined countercurrent chromatography – inductively coupled plasma mass spectrometry method for the determination of ultra trace uranium and thorium in Roman lead.", Talanta 192, (**2019** - in press), 395-399.

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.

February 12, 2018. PhD thesis by S. Rozov, "Поиск частиц темной материи в эксперименте EDELWEISS".

2019: E. Yakushev, doctor of science thesis, in preparation

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.

New Trends in High-Energy Physics, 24-30 September 2018, "Direct low-mass WIMP searches with HPGe Semiconductor Bolometers", S. Rozov

New Trends in High-Energy Physics, 24-30 September 2018, "Modern approaches in ultra-low background experiments at the LSM underground laboratory", E. Yakushev

International Session-Conference of the Nuclear Physics Section of the Physical Sciences Department of the RAS (NPS PSD RAS), «Physics of Fundamental Interactions», 12-15 April 2016, "Experimental search for Dark Matter", E. Yakushev

6b. Give a similar list for parallel talks.

VLVnT-2018, 2 - 4 October 2018, "Direct Dark Matter searches: overview", E. Yakushev

Nucleus-2018, 1-7 July 2018, "Low neutron flux measurements in underground laboratory in Modane using iodine-containing scintillators", D. Ponomarev

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.

EDELWEISS is a small international collaboration that includes about 50 scientists from France, Germany and JINR.

JINR group human resources are:

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	0.1
Z. Kalaninova	Researcher	MC, data analysis	0.2
A. Lubashevskiy	Senior Researcher	MC, running of JINR low threshold detectors, radon measurement, data analysis	0.2
D. Filosofov	Head of sector	Radiochemistry, low background technique	0.3
N. Mirzaev	Junior researcher	Radiochemistry, low background technique	0.3
L. Perevoshchikov	Researcher	Nuclear spectroscopy	0.2
D. Ponomarev	Engineer	Neutron background measurements, detectors building, testing. Experiment running.	0.5
A. Rakhimov	Junior researcher	Radiochemistry, neutron activation analysis, nuclear spectroscopy	0.3
I. Rozova	Engineer	Data analysis	0.5
S. Rozov	Engineer	Background study and improvement, detector building, testing, calibration, running.	0.7
K. Shakhov	Engineer	Radon gas, radon emanation detection / development and measurements	1.0

E. Yakushev	Head of sector	Administrative work, radon and neutron measurements, detectors building, commissioning, running	0.7
Total FTE (Engineers): 2.7, Total FTE (Scientific staff): 2.3, Total FTE: 5.0			

In JINR the EDELWEISS project is conducted under scientific theme "Non-Accelerator Neutrino Physics and Astrophysics", thus all common resources of the theme are used.

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

The scientific core of the JINR team of the project will be stable and includes: D. Filosofov, A. Lubashevskiy, S. Rozov and E. Yakushev. In the same time EDWIGE EDELWEISS branch that is in our complete responsibility will require more man power and that will be shared with the GEMMA project.

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 EDELWEISS project is 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. Implementation of projects conducted under the theme relates to common approaches and resources. In addition to five scientific sectors involved in the theme, the following resources are available to carry out the scientific projects: the laboratory for the production and repair of semiconductor detectors; laboratory for creation and production of scintillation materials for detectors; radiochemical sector (creation of calibration radioactive sources, purification of materials designated for low-background measurements from their contamination by natural radioactivities, etc.), mechanical workshops, a group of computer support, a group of mass separators and others.

EDELWEISS-only requested resources are reflected into the forms No.26 and No.29 of the written project (PAC-NP, January 2018) - duplicated on the next pages.

Form No. 26

Schedule proposal and resources required for the implementation of the Project

EDELWEISS-LT

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 required for tests of low threshold detectors (shielding, veto system, etc). Materials and equipments for the clean room.		30	10	10	10
	2. Spectroscopic electronics for point contact detectors at LSM.		15	5	5	5
	3. Low background neutron spectrometers with iodine containing detectors.		15	5	5	5
	4. Materials and equipment for maintenance of JINR EDELWEISS detectors (three neutron detectors, two radon detectors, alpha spectrometer, HPGe spectrometer).		21	7	7	7
	5. Materials and equipment for calibration purposes. It includes making of new radioactive source. Radiochemistry equipment		15	5	5	5
Resources	Norm-hours	JINR workshop	3300	1100	1100	1100
		DLNP workshop	1500	500	500	500
Financial sources	budget	Budget spending	**105**	**35**	**35**	**35**
	Off-budget resources	Grants; Other sources (these funds are not currently guaranteed)	*30*	*10*	*10*	*10*

Form No. 29

Estimated expenditures for the Project EDELWEISS-LT, Direct low-mass WIMP searches with HPGe Semiconductor Bolometers

#	Designation for outlays	Total cost	1 year	2 year	3 year
	Direct expenses for the project				
1.	Networking	3.0K US$	1.0	1.0	1.0
2.	DLNP workshop	1500 norm-hours	500	500	500
3.	JINR workshop	3300 norm-hours.	1100	1100	1100
4.	Materials	36.0K US$	12.0	12.0	12.0
5.	Equipment	69.0K US$	23.0	23.0	23.0
6.	Collaboration fee	60.0K US$	20.0	20.0	20.0
7.	Travel expenses	60.0K US$	20.0	20.0	20.0
	Total	**228.0K US$**	**76.0K US$**	**76.0K US$**	**76.0K US$**

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

N/A.