# Annotation of the EDELWEISS-LT project
# Direct low-mass WIMP searches with HPGe Semiconductor Bolometers

JINR group: *V. Brudanin, Z. Kalaninova, A. Lubashevskiy, D. Filosofov, N. Mirzaev, L. Perevoshchikov, D. Ponomarev, A. Rakhimov, I. Rozova, S. Rozov, K. Shakhov and E. Yakushev*

## Introduction and general description of the EDELWEISS setup:

The EDELWEISS program searches for direct evidence of Dark Matter (DM) WIMPs from the Milky Way galaxy through their scattering of Ge nuclei within cryogenic Ge crystals. The EDELWEISS detectors are cryogenic (work temperature is about 20 mK) Ge bolometers with simultaneous measurement of phonon and ionization signals. The comparison of the two signals provides event-by-event discrimination between nuclear recoils (induced by WIMP and also by neutron scattering) and electrons. EDELWEISS collaboration demonstrated that the main background limiting the sensitivity of the Ge based (and other) experiments arises from the inability to reject events occurring close to the surface of the detector, for which a deficient charge collection can mimic the ionization yield of nuclear recoils. Therefore detectors for EDELWEISS were developed with an innovative interleaved electrode design, able to discriminate against events occurring within 1 mm from the detector surface. The developed technology shows unprecedented and world-leading improvement of surface background suppression.

The EDELWEISS experiment is set in the Laboratoire Souterrain de Modane (LSM), under 1800 m of rock overburden (~4700 mwe). The heart of the EDELWEISS experiment is $^3$He-$^4$He dilution cryostat with HPGe detectors-bollometeres. The EDELWEISS shielding concept shown on the Fig. 1 includes the surrounding of detectors by 20 cm of Pb (include internal layer from archaeological roman lead), 50 cm of polyethylene and active $\mu$-veto. The cryostat environment is supplied with radon-free air. The setup with all shielding is located in an air-tight and pressurized clean room of class 1000. The radioactivity levels of all construction materials were tested prior to their use.

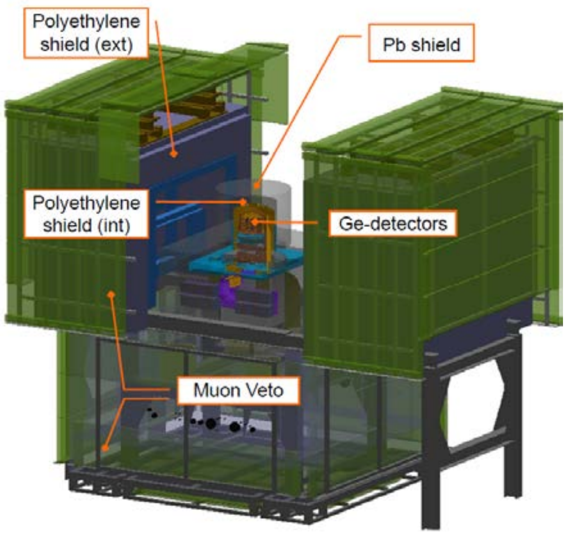


*Fig. 1: Scheme of EDELWEISS setup.*

In the present time there is an increasing gain of interest for the search of low-mass WIMPs arising on the one hand from non evidence yet for SUSY at the LHC and on the other hand from new theoretical approaches favoring lighter candidates. As an example, asymmetric DM models linking the relic density to the baryon asymmetry predict DM particles of a few GeV/c$^2$. Thus main objective of the EDELWEISS is now shifted to the low-mass WIMPs region (10 GeV/c$^2$ and below) which could investigated in the experiment thanks to advantage of 100 eV energy resolution reachable with HPGe bolometers via the Neganov-Luke effect of internal amplification of the heat signal.

## Current phase experimental results:

At the current stage of the experiment the most important from result is connected with investigation of low-mass WIMPs region from 4 to 30 GeV/c$^2$ (Fig. 2). For the extreme case for WIMPs with $m_\chi$ = 4 GeV/c$^2$ the 90 % C.L. exclusion limit set currently by EDELWEISS is 1.6 × 10$^{-39}$ cm$^2$. Therefore, positive results reported by some others experiments were directly verified.

It is important that the achieved by EDELWEISS-III sensitivity completely covered region of positive CoGeNT results obtained on the same nuclear (Ge).

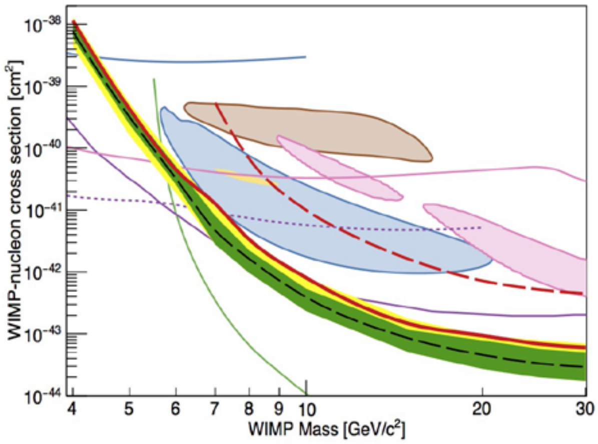


*Fig. 2: Red curve: 90% CL limit on the spin-independent WIMP-nucleon cross-section obtained by EDELWEISS. The green (resp. yellow) band represents the expected 1σ (resp. 2σ) sensitivity region in the absence of a signal. The yellow, blue, pink and brown contours are respectively from CoGeNT, CDMS-Si, CRESST-II and DAMA. We also represent other limits by EDELWEISS-II (dashed red), LUX (green), DAMIC (blue), CRESST (pink), CDMSLite (dashed violet) and SuperCDMS (violet).*

**EDELWEISS-LT**

During the EDELWEISS-LT phase of the project measurements with several low threshold bolometers using Neganov-Luke effect of internal amplification of the heat signal will be performed. That will target light WIMP - nucleon cross section on the level of better of $10^{-41}$ cm$^2$ competitive with best results of other experiments. The EDELWEISS-LT will be based on the same experimental infrastructure (shield, dilution cryosystem and low background cryostat, acquisition system) that is currently available in the LSM underground laboratory.

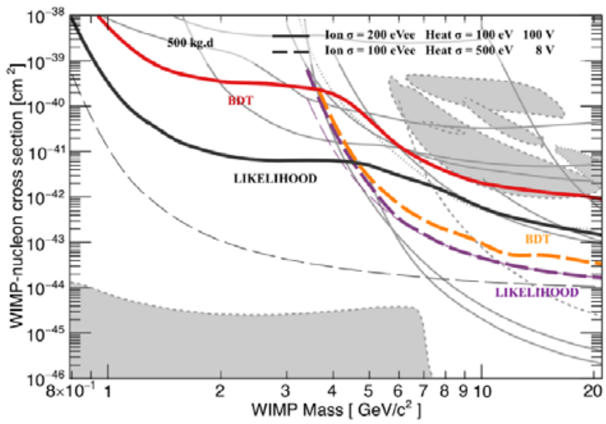


*Fig. 3: EDELWEISS-LT projected sensitivities with current background. Exclusion limits are derived from BDT and profile likelihood ratio approaches and for the two extreme bias voltage conditions (8V, 100V). Below masses of 5 GeV/c$^2$, the best sensitivity will be obtained by lowering the thresholds, with the Luke-Neganov boost corresponding to a bias voltage of 100V, keeping current ionization resolution at 200 eVee and improving heat resolution to 100 eV. Official EDELWEISS-LT low-mass projected sensitivity is thus given by the black solid line exclusion limit. The background-free sensitivity is shown in thin dashed lines.*

Fig. 3 presents the two major scenarios for near future low-mass WIMP search with EDELWEISS-LT, considering efforts have been put on the R&D, aiming at improving at least one of the energy resolutions, either for heat or for ionization signals. Sensitivities have been computed with both boosted decision tree (BDT) and likelihood methods for a total exposure of 500 kg d with our current background levels and setup at the LSM. Improving ionization resolution could be done through the implementation of High Electron Mobility Transistors (HEMT) to replace Junction Field Effect Transistors (JFET) used for charge measurements on the Al electrodes collecting electron-hole pairs. Concerning heat resolution improvement, dedicated R&D is also in progress on baseline performance with the achievable objective of reaching $\sigma_{Eheat}$ = 100 eV: a coherent thermal model has been constructed by EDELWEISS and is used to extract relevant parameters of the heat signal in order to build new thermal sensors which would provide the expected heat energy resolution improvement. It could lead to nuclear recoil energy thresholds ranging from 400 to 100 eV$_{nr}$, depending on the applied bias voltage across the crystal.

Further ahead the requirements to the EDELWEISS-LT will to approach the neutrino floor, which corresponds to the coherent scattering of solar $^8$B neutrinos. Fig. 4 shows sensitivity projections derived from the likelihood analysis for a large exposure of 50000 kgd and resolutions of both heat and ionization channels at 100 eV. Limits are computed for both 8 V and 100 V bias voltages and plotted in purple and black, respectively. Solid lines of Fig. 4 correspond to the expected limits achievable considering the current EDELWEISS background budget, with the exception of heat-only events, which are supposed to be completely suppressed. Thick dashed lines (dot dashed lines) are obtained assuming not only no more heat-only events (a reduction of heat-only events by a factor 100), but also no more neutrons and a reduction of the Compton background by a factor 10. The background-free sensitivity is shown in thin dashed lines.

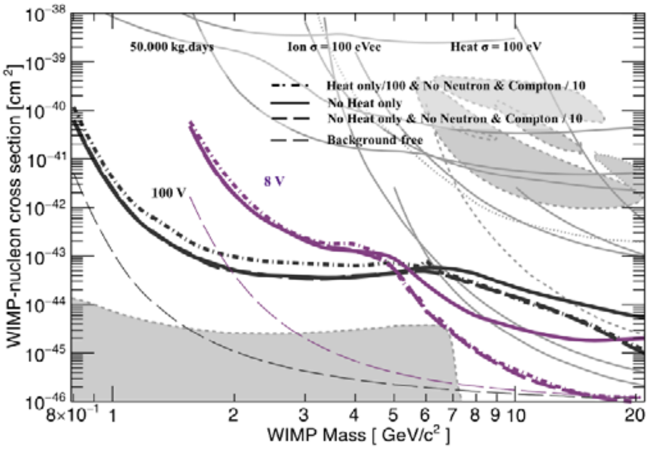


*Fig. 4: Projected sensitivities for a large exposure of 50000 kgd with strongly improved background levels and R&D upgrade performance achieved, with baseline resolutions of heat and ionization channels at 100 eV. Limits are computed using a likelihood analysis at 8 V (purple) and 100 V (black) assuming a suppression of the heat-only background (solid line), and no more neutron background associated with a reduction of the Compton background by a factor 10 (thick dashed line). The background-free sensitivity is shown in thin dashed lines*

**Dubna group responsibilities**

Dubna team of the EDELWEISS project is formed on the base of Department of Nuclear Spectroscopy, DzLNP. This department has huge almost 50-years experience in high-precision nuclear spectroscopy using semiconductor and scintillator detectors in general and 30-years experience of rare process study in underground environment.

JINR team of the project is expected to contribute to: 1) Development of new low threshold Ge detectors; Assembly and commissioning; 2) Development of methods for underground site low background measurements; 3) Data taking (this includes daily routine procedures, as well as regular and special calibration runs); 4) Low background study and development of methods of neutron and radon detection; 5) Detector simulations and data analysis; Publication of results.

Main participation of JINR in the EDELWEISS-LT projects will be in providing of expertise on background connected problems as well conducting of measurements of backgrounds and selection of radio-pure materials (which are needed for new detectors: supports, cables, electronic circuits, etc). We will continue study of neutrons and radon at the deep underground site. Our activity in the experiment will also includes WIMP data analysis and MC of detectors. JINR group will also perform other tasks it is responsible for: as for example the calibration of EDELWEISS detectors with radioactive neutron and gamma sources.

The Dubna group is also responsible for R&D, installation and running of point contact detectors in frame of theEDELWEISS collaboration. This work is extremely important for JINR since provides base and infrastructure for development and test of low radioactive low energy threshold setups for neutrino experiments at Kalinin NPP. The EDELWEISS-I shield is provided for the point contact detector tests. In the same time other facilities as clean room, radon-free air, etc are also available and used. In 2018 JINR group will start of tests of unique point contact detectors with masses from 1 to 1.5 kg and with energy thresholds at about 200 eV.