Status of the EDELWEISS-II experiment

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Abstract. The Edelweiss programme is dedicated to the direct search for Dark Matter as massive weakly interacting particles (WIMPs) with Germanium cryogenic detectors operated in the Laboratoire Souterrain de Modane in the French Alps at a depth of 4800 mwe. After the initial phase Edelweiss I, which involved a total mass of 1 kg, the second step of the programme, Edelweiss II, currently operates 9 kg of detectors and an active shielding of 100 m² muon veto detectors and is now in its commissioning phase. The current status and performance of the Edelweiss II set-up in terms of backgrounds will be given, the underground muon flux measured with the muon veto system will be presented.

1. Introduction
Understanding the nature of Dark Matter in the universe is a major challenge for modern cosmology and astrophysics. One of the well-motivated candidates is the generically named Weakly Interacting Massive Particle (WIMP). In the Minimal Supersymmetric Standard Model (MSSM) framework, the WIMP could be the Lightest Supersymmetric Particle, which is stable, neutral and massive.

The French-German-Russian EDELWEISS (Expérience pour DEtecter Les Wimps En Site Souterrain) experiment is dedicated to the direct detection of WIMPs trapped in the galactic halo. The detection is performed through the measurement of the recoil energy produced by the elastic scattering of a WIMP off target nuclei.

The main challenges are the extremely low event rate of < 1 evt/kg/year and the relatively small deposited energy of < 100 keV.

2. Experimental setup and detectors

2.1. Set up
The EDELWEISS experiment is situated in the Laboratoire Souterrain de Modane (LSM) in the Fréjus Tunnel highway connecting Lyon to Turin behind the French Alps. The 1800 m of rock (4800 mwe) reduces the muon flux down to 4 m/m²/day, a factor 10⁶ times less than at the surface. The EDELWEISS-II experiment installation (see figure 1) was completed end of 2005. Specific improvements have been brought to reduce the possible background sources that have limited the sensitivity of EDELWEISS-I [1,2].

The gamma background is screened by a 20 cm thick lead shielding. All the materials used in the vicinity of the detectors have been tested for their radiopurity with a dedicated HPGe detector. A class 10 000 clean room surrounds the whole experiment and a class 100 laminar flow with deradonised air (< 0.1 Bq/m³) is used when mounting the detectors in the cryostat. In the experimental volume the low energy neutron background in the cavity is attenuated by three orders of magnitude thanks to a 50 cm thick polyethylene shielding. In addition a 100 m² plastic scintillator active muon veto surrounding the experiment with a coverage of 99% will tag muons interacting in the lead shielding and producing neutrons. The residual neutron background comes from high energy neutron produced by muon that are not tagged by the veto system and by the neutrons from ²³⁸U fission in the lead shielding. Initial Monte Carlo simulation showed that the recoil rate above 10 keV in the detectors is around 0.002 evt/kg/day equivalent to a sensitivity to WIMP-nucleon cross-section of 2.10⁻⁸ pb for WIMP masses around 100 GeV/c². This corresponds to an improvement of a factor 100 compared to EDELWEISS-I sensitivity.
The dilution cryostat used in the experiment is of reversed design, with the experimental chamber on the top of the structure. It is a nitrogen-free system, using three pulse tubes to cool the 100 K and 200 K screens and a He reliquifier reducing the He consumption. The experimental volume is about 50 liters allowing the installations of 110 detectors of about 330 g each in a compact arrangement for self shielding and multiple interactions identifications.

![Figure 1. General scheme of the EDELWEISS-II experiment](image)

### 2.2. Detectors

EDELWEISS uses high purity Germanium cryogenic detectors with simultaneous measurement of phonon and ionization signals at a temperature of 20-40 mK. A nucleus produces less ionization in a crystal than an electron does, allowing an excellent event-by-event discrimination between nuclear recoils (induced by WIMP or neutron scattering) and electron recoils (induced by $\alpha$, $\beta$ and $\gamma$ radioactivity).

The actual limitation of our present detectors arises from incomplete charge collection for near-surface events. To reach sensitivities to cross-section of interest for SUSY Models it is necessary to improve the rejection capabilities of the detectors in parallel with the active mass.

For this purpose, EDELWEISS-II will run three different types of detectors: (i) the known 320 g Ge/NTD EDELWEISS-I type equipped with new holders, (ii) the 400 g Ge/NbSi [3,4] with two NbSi Anderson insulator thermometric layers for active surface events rejection that have been developed within EDELWEISS collaboration, (iii) a new type of detectors, the 400 g Ge/NTD/INTERDIGIT recently developed [4,5] with the same aim to active surface events rejection thanks to a special interdigitized electrodes scheme. The surface events rejection capabilities of Ge/NbSi and Ge/NTD/INTERDIGIT have been measured in labs and are better than 99%[5,6] for events occurring in the first millimeter under the surfaces.

After the current commissioning phase, data for WIMP search will be acquired with 21 Ge/NTD and 7 Ge/NbSi starting from the fall. Additional prototypes of 400 g Ge/NTD/INTERDIGIT will also be measured. Forty additional detectors (50% Ge/NbSi and 50% Ge/NTD/INTERDIGIT) will be added in the two coming years to enhance progressively the sensitivity.

### 3. Calibration commissioning runs

In comparison with EDELWEISS-I, EDELWEISS-II is a completely new experiment: new cryostat (up to 110 detectors), new electronics, new acquisition hardware and software and a fully numerical triggering system.
Four cryogenic runs with 8 detectors have been done in 2006 to check and validate the different parts of the setup. This whole year has been dedicated to the tuning of the electronics and improvements on the acquisition and cryogenics, especially for acoustic and mechanical decoupling of the thermal machines. The quasi-total 28 detectors stage (21 Ge/NTD, 4 Ge/NbSi) has been mounted early 2007 for commissioning runs.

During the last run, the mean phonon channel energy resolution (for a charge collection voltage of 5 V) was measured to be 2 keV while best results are at 1.2 keV level for the Ge/NTD detectors. The detectors were operated at 24-26mK with resistances under bias around 1 Mohms. For some detectors, the resolution is still degraded by the noise induced by the pulse tubes and reliquefier and work is in progress to achieve a resolution close to 1 keV for all detectors. Ge/NbSi detectors in operation at this date were showing excess heat capacity of the niobium electrodes that degraded the resolution to around 15 keV for thermal signal and 5 keV for athermal signal. This problem has been solved by using aluminium electrodes and heat resolution of 5 keV and 2 keV for thermal and athermal signal should be obtained for the future detectors. Energy resolutions of the ionization channels were around 1.5-2 keV for both type of detectors.

![Figure 2](image.png)

**Figure 2.** Ionisation/recoil energy ratio versus recoil energy in keV for 8 detectors with recoil thresholds between 20 and 35 keV. On the left, neutron calibration with an Am-Be source, on the right gamma calibration with $^{133}$Ba sources. 90 and 99.9% acceptance band are shown.

Neutron and gamma calibration for the 8 Ge/NTD detectors with the best energy resolutions are shown on figure 2. Discrimination capabilities better than 99.9% are obtained, which is similar to EDELWEISS-I performances. The recoil energy threshold varies from 20keV to 35keV.

4. **Low background commissioning runs**

To quantify the alpha, gamma, and beta backgrounds, low background runs have been performed. The aim of these runs is to measure the rate of miscollected surface events in the detectors in the EDELWEISS-II setup and to extrapolate future sensitivity.
Figure 3. Ionization energy spectrum for low background run for the Ge/NTD detectors (65 kg.d for the total volume). The comparison with EDELWEISS-I gamma background shows an improvement of a factor 2 at low energy. The alpha background are identified by selecting events with an ionisation/recoil energy ratio less than 0.5.

The electronic recoil background rate is shown on figure 3. For the fiducial volume, this rate is around 0.6 evts/kg/day below 100keV which is a factor 2.5 better than EDELWEISS-I. The alpha background is between 1.6 and 4.4 alpha/kg.day (75-200 alpha/m²/day) depending on the detector and its near-by environment. The mean alpha rate was 4.2 alpha/kg/day for EDELWEISS-I.

Figure 4 shows the ionisation/recoil energy ratio as a function of the recoil energy for low energy background runs taken at the end of the commissioning period. Results for an exposure of 19.3 kg.day for the fiducial volume of the 8 Ge/NTD detectors with low thresholds are shown on the left. The rate of bad collected events measured with the method defined in ref 1 is 1.1±0.3 evts/kg/day which is close to EDELWEISS-I results. However, no events are seen in the nuclear recoil band signal, showing a possible improvement relative to EDELWEISS-I, where 3 events were measured with similar exposure. More statistics are obviously needed to draw firm conclusions. Results obtained with a 200g Ge/NbSi detectors is shown on the right for a fiducial exposure of 1 kg.day after the cuts of the surface events. The discrimination parameter is obtained with the athermal phonon signal which causes the rather large dispersion around 1. The Ge/NbSi analysis is explained in details in ref 4.
5. Muon veto measurement and simulations

The veto system consists of 42 plastic scintillator modules of 65 cm width, 5 cm thickness and lengths between 2 m and 4 m. The total surface is about 100 m² surrounding almost hermetically the outer polyethylene shielding of the cryostat. Each scintillator module is read out at both ends yielding 84 channels for the muon veto data acquisition system. From a subset of data taken from November 2006 to July 2007, a rate of \(11.2 \pm 0.3\ \mu/d\) has been measured with this setup, while the expected rate taking into account the profile of the mountain \([7,8]\) has been evaluated to be \(12.5 \pm 0.4\ \mu/d\). Study of coincidences between muon veto and bolometers will be performed in the following months.

In addition, recent and accurate simulations \([8]\) taking into account the deposited energy by muons and associated showers in plastic scintillator detectors show that a significantly larger than anticipated fraction of muon induced showers could be tagged by lowering the threshold in these detectors, thus allowing a potential increased sensitivity of the setup to lower WIMP cross sections. To complete the muon veto installation, a new large (around 1 ton) neutron liquid scintillator detector will be soon operated close to the muon veto and will allow to evaluate the muon induced neutron flux.

6. Tools for background monitoring

We have been developing and are now operating in the environment of Edelweiss set up a \(^{3}\)He neutron monitor sensitive to flux of about \(10^{-8}\) thermal neutron \(/cm^2/s\) and a radon monitor with a sensitivity to concentration of radon in air of few mBq/m³. In addition, a 50 g sapphire scintillation-phonon detector has been successfully operated. The potential for neutron detection with light elements, such as those in sapphire, is being evaluated.

7. Conclusion and prospects

The EDELWEISS-II setup has been validated with calibration and low energy background runs. Energy resolutions and discrimination capabilities close to EDELWEISS-I results have been measured for Ge/NTD detectors. Validation of Ge/NbSi detectors with new aluminium electrodes is in progress and Ge/NTD/INTERDIGIT detectors have shown promising results in surface lab. Low backgrounds physics runs will be taken with the 28 detectors setup with the aim to reach sensitivity to WIMP-nucleon cross-section of \(\sim 10^{-7}\) pb for a WIMP mass of 100 GeV. Additional detectors with active surface rejection capabilities will be installed in the two coming years to enhance progressively the sensitivity to WIMPs. Muon veto and neutron detector will provide a unique tool to understand and limit the ultimate neutron background from muons.

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