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EDELWEISS dark matter search: Latest results and future plans

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EDELWEISS is a direct search for WIMP dark matter using cryogenic heat-and-ionization germanium detectors. We report the final results of the second stage of the experiment, EDELWEISS-II, obtained with an array of ten 400 g detectors. A total effective exposure of 384 kg.day has been achieved, obtained following fourteen months of continuous operation at the Laboratoire Souterrain de Modane. Five nuclear recoil candidates are observed above 20 keV, while the estimated background is less than 3 events. We also present the prospects of EDELWEISS-III, which plans to accumulate more than 3000 kg.day of data with fourty new 800 g detectors.

1 The EDELWEISS-II experiment

The EDELWEISS [2] experiment is dedicated to the direct detection of WIMPs trapped in the Milky Way 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 constraints are the extremely low event rate (<1 evt/kg/year) and relatively small deposited energy (in the tens of keV range). The goal of the phase II of the project is to explore wimp-nucleon cross section of a few 10^{-8} pb, thus requiring a background of less than 10^{-3} nuclear recoil candidate per kg.day above 10keV. For the search, the detectors are operated in a radiopure underground environment located in the Laboratoire Souterrain de Modane (LSM) where the 4850 meter-water-equivalent rock cover reduces the cosmic-ray background by six order of magnitude. The experiment is protected by the *gamma*-ray background with a 20 cm lead shield and through a very careful selection of all materials. A clean room surrounds the whole experiment and a class 100 laminar flow with deradonised air (<0.1 Bq/m^3) is used when mounting the detectors. Fast neutrons are a particular background as their scattering in the detector can induce germanium recoil similar to those expected from WIMPs. The fast neutron flux is moderated through a 50 cm polyethylene shield surrounding the lead shield. It has been measured to be 10^{-6} n/cm^2/s above 1 MeV. A muon veto with a 98% geometric efficiency surrounds the polyethylene shield, in order to tag neutrons created by muon interactions inside the lead shield. The experimental volume is about 50 liters allowing the installation of up to 40 kg of detectors in a compact arrangement for self shielding and multiple interaction identification. EDELWEISS uses high purity Germanium cryogenic detectors with simultaneous measurement of phonon and ionization signals at $\approx$ 20 mK. A nucleus recoil produces approximately three times less ionization than an electron recoil does, allowing an excellent event-by-event discrimination between nuclear recoils (induced by WIMPs or neutron scattering) and electron recoils (induced

by α, β and γ radioactivity). The actual limitation of this technique arises from incomplete charge collection for near-surface events (mainly low energy electrons from residual ^{210}Pb, a daughter of radon that is present on all surfaces): because of diffusion, recombination and trapping processes a small fraction of surface events could be miscollected and even mimic nuclear recoil interactions. The EDELWEISS collaboration has recently developed a new type of detectors, the so-called ID (InterDigit) detectors [1] with an active surface event rejection based on a special interdigitized electrodes scheme. The detectors are made from hyperpure germanium crystal of cylindrical shape with a diameter of 70mm and a height of 20mm. Each flat surface is covered with concentric aluminum ring electrodes of 2mm pitch regrouped in two sets of electrodes connected alternatively by ultrasonic bounding. Two additional plain guard electrodes cover the outer edges of the crystal. With the additional cut on the interleaved electrodes, corresponding to depth down to 1mm below the flat surfaces, the resulting fiducial volume per detector is 165 g.

2 EDELWEISS-II results

A WIMP search was carried out using ten 400-g ID detectors from April 2009 to May 2010. During the whole acquisition period, the cryogenic conditions were maintained stable at 18 mK.

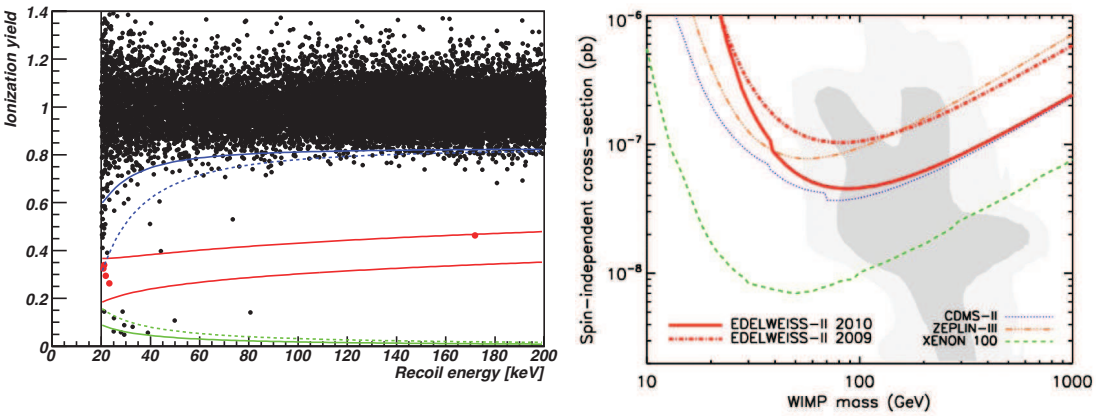

Figure 1: Left pannel: Ionization yield as a function of recoil energy for the 384 kg·d exposure collected by EDELWEISS for its WIMP search with ten 400g ID detectors. Right pannel: Limits on the cross-section for spin-independent scattering of WIMPs on the nucleon as a function of WIMP mass, derived from the present work, together with the limits from CDMS [4], ZEPLIN [5] and XENON100 [6]. The shaded area correspond to the 68% and 95% probability regions of the cMSSM scan from Ref. [8].

Most of the time was devoted to WIMP search (325 days), and a small fraction to gamma and neutron calibrations (10.1 and 6.4 days). The data were analysed using two independent pipelines which yield consistent results. The average baseline resolutions of heat and fiducial ionization channels were of ≈1.2 keV FWMH and ≈0.9 keV FWHM, respectively. WIMPs interaction candidates were searched among fiducial events in the 90% CL nuclear recoil band. Tagging of coincident events in bolometers and the muon veto allowed to reject neutron-induced

recoils. A WIMP- search energy threshold was set a priori to 20 keV, energy above which efficiency is independent of the energy. After all cuts, the effective exposure obtained is 384 kgd. The analysis procedures and results are described in details in [2]. ¿From the γ-ray calibration we obtain a γ rejection factor of $\approx 3.10^{-5}$. The origin of the six events leaking into the nuclear recoil band is being investigated but we can see on Figure 1. that the rejection is improved significantly with the new FID detectors without guard rings. Five events are found in the nuclear recoil band: four of them have energies between 20 and 23 keV, and one has 172 keV. All of them are well-reconstructed events, which lie well above the noise level of the detectors. Background studies are still ongoing to fully understand their origin. Upper limits may be derived from the known residual gamma, beta and neutron backgrounds, using calibration data, material radioactivity measurements and Monte Carlo simulation of the detectors. Overall, less than 3 events (90% CL) from known origin are expected. The spin-independent cross-section upper limit for WIMP-nucleon elastic scattering is calculated using the standard Yellin prescription 8 and halo model and parameters. The best sensitivity obtained by EDELWEISS-II is $4.4.10^{-8}$ pb at M_χ=85 GeV. These data have been also interpreted in the inelactic dark matter scenario[2]. The resulting limits are shown in the right pannel of Figure 1, compared with those of other direct WIMP searches [4, 5, 6]. The data has a significant impact on the total sensitivity obtained when combining it with the results of the other search using cryogenic germanium detectors, CDMS [7].

3 The EDELWEISS-III project: setup and detectors

The Inter-Digit detector technology has proven to be reliable and robust enough to perform direct detection of WIMPs at the highest level of the competition. To go beyond the present performances, a new generation of detectors has been developed with interleaved electrodes covering also the lateral surfaces of the crystal: the Full Inter-Digit (FID). A first series of four detectors has been tested. The combination of an unprecedented mass of 800 g and the FID technology increases significantly the fiducial mass of the detectors to $\approx$600g (it was $\approx$165g for the ID). In addition to this, the FID800 series benefits from two NTD sensors to have redundancy also in the heat measurement and new surface treatments to increase the surface event rejection [3]. The construction of an array of forty 800 g detector, to be completed by 2012, is in progress, with a projected sensitivity of WIMP scattering cross-section of 5×10^{-9} pb. This third stage of EDELWEISS will also see its cryogenics and electronics being upgraded for achieving a recoil energy analysis threshold below 15 keV. Further developments are being studied in the framework of the EURECA [9] collaboration, aiming for an experiment in the future extension of the underground laboratory at LSM, with a sensitivity goal of 10^{-11}pb . This project brings together the European efforts of EDELWEISS and also of the CRESST and ROSEBUD teams working on heat-and-scintillation detectors, to built a ton-scale multi-target array of cryogenic detectors.

4 Acknowledgments

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