EDELWEISS-II : status and first results

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Abstract. The EDELWEISS-II experiment is devoted to the direct detection of WIMP dark matter, using a new generation of cryogenic germanium detectors. We will present preliminary results of the first operation of these detectors installed in the Modane underground laboratory. Very low radioactive background conditions are achieved. Furthermore, these new detectors, with a special electrode design for active rejection of surface events, have been experimentally shown to be suited for WIMP searches with spin-independent scattering cross-sections on a nucleon well below 10^{-8} pb. Preliminary results of WIMP searches performed with a first set of these detectors will be shown as well.

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PRESENTATION OF THE EXPERIMENT

In order to detect the nuclear recoils due to elastic scatterings of WIMP dark matter located in the galactic halo, highly sensitive detectors must be designed. Low backgrounds and an active discrimination against the residual backgrounds must be achieved. Furthermore, detectors must have a low threshold to be sensitive to the exponential distribution of the recoils.

The EDELWEISS experiment uses HPGe single crystal cryogenic detectors measuring simultaneously ionization and heat signals. Electron-hole pairs produced by the interaction of a particle are detected using a low electric field between electrodes on each side of the crystal. The rise in temperature is measured by a Neutron Transmutation Doped (NTD) thermometer whose resistance depends strongly on the temperature around 20mK. The ionization yield being higher for electron recoils than for nuclear recoils, an event by event discrimination is made based on this parameter enabling the rejection of gamma radioactivity. Lead and polyethylene shields surrounding the detectors, together with a systematic selection of low radiopurity materials, reduce the level of radioactivity. In addition a plastic scintillator muon veto enables the active rejection of nuclear recoils due to muon-induced neutrons with high efficiency. The setup is described in [1].

SURFACE EVENT REJECTION WITH ID DETECTORS

The main limiting background of the experiment comes from interactions occurring just underneath the collecting electrodes : these are essentially β-rays from the ^{210}Pb contamination of the detector surface and/or in the vicinity of the detectors. These events have an incomplete charge collection that can mimic nuclear recoil and limit the

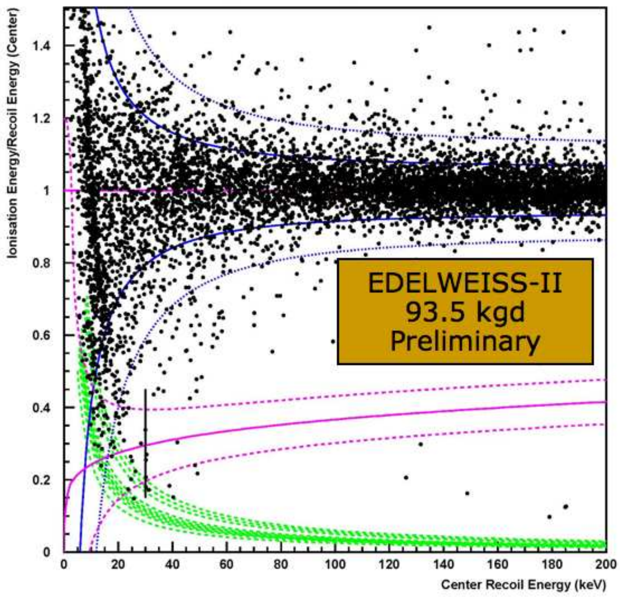

FIGURE 1. Ionisation yield vs recoil energy for a 93 kg.day exposure using 11 old-generation detectors. The leaking events down to the nuclear recoil band are attributed to beta interactions.

sensitivity of the experiment. This may be seen in data taken in 2008 with old-generation detectors : an exposure of 93 kg.days was achieved using 11 detectors and an analysis threshold set *a priori* to 30 keV. The beta background was reduced with respect to former EDELWEISS-I background runs but, as can be seen in Fig. 1, it is still the limiting factor to improve the sensitivity.

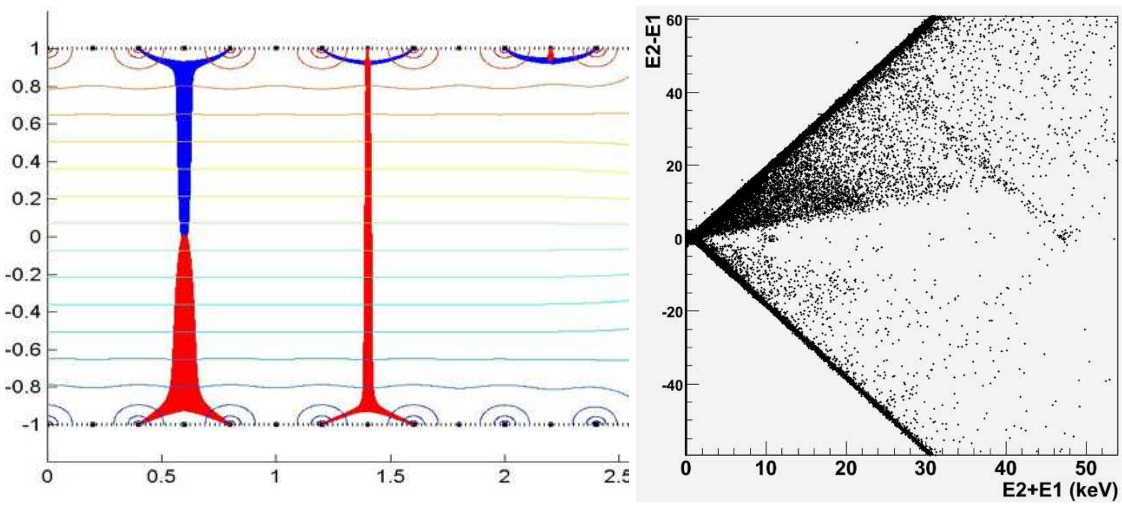

FIGURE 2. Left: sectional view of an ID detector, with the corresponding equipotential lines and the drift of charges represented for 3 different event locations. Right : difference of signals between the two collecting electrodes as a function of the energy for a calibration with two ^{210}Pb sources facing each face of the detector with two different rates. The majority of interactions with $E_1 \neq E_2$ are β events. The γ-ray line at 46 keV is observed, with interactions occuring at the boundary of the fiducial volume.

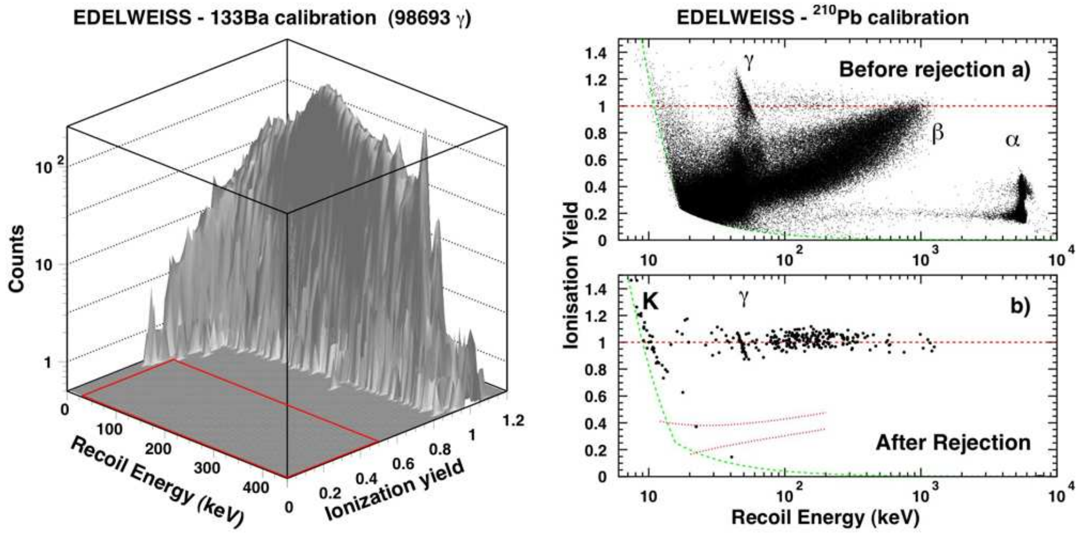

FIGURE 3. Left: ID detectors calibration with γ-rays from ^{133}Ba sources, no event is present in the region with $Q < 0.5$ where the WIMP signal is expected. Right: ionization yield as a function of recoil energy recorded in ID detectors during a calibration with a ^{210}Pb source. The comparison of panels (a) and (b) demonstrates the high efficiency of surface event rejection on the population of α, β particles and near-surface γ rays from the source.

New detectors, named InterDigits (IDs), were developped in order to reject this background (Fig. 2 left). They take benefit of the splitting of the center electrode in two sets of interleaved rings polarized differently ([2, 3]). This electrode design keeps the cylindrical symmetry of the crystal. The B and D set of rings contribute to the collection of charge only for events which take place close to the surface. If only A and C sets of rings are collecting charges then the event can be considered as volume events. B and D act as veto against surface events. To illustrate the power of the discrimination against surface events, we show in Fig. 2 (right) the scatter diagram of the difference of amplitudes of collecting electrodes versus their sum, for a calibration run performed with beta sources (^{210}Pb). Volume events are along the horizontal axis and are well separated from surface events which are mostly located on the two main diagonals.

Fig. 3 shows the ionisation yield as a function of recoil energy for high-statistics calibrations performed with a ^{210}Pb source (right) and a ^{133}Ba source (left). For the beta calibration, one event is present after the fiducial selection in the nuclear recoil band where the WIMP signal is expected, and none for the gamma calibration. These measurements give rejection factors of about 1 in 10^5 for beta rays and better than 1 in 10^5 for gamma rays below 60keV. Such performances are described in more details in [4], and open the way to spin-independent WIMP sensitivities below 10^{-8} pb.

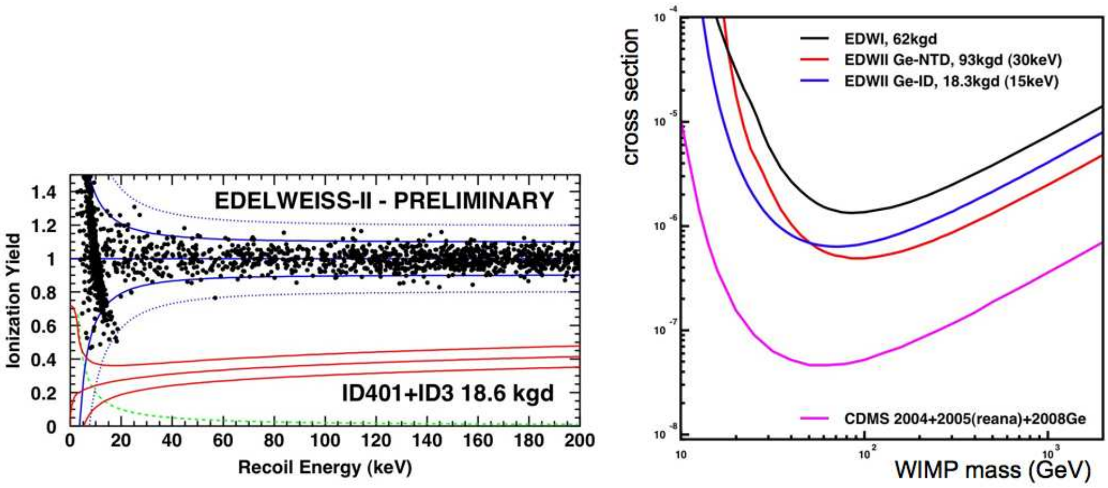

FIGURE 4. Left: Ionization yield versus recoil energy recorded in EDELWEISS ID detectors for an exposure of 18 kg.days. Right: 90% CL limits for spin-independent scattering cross-section for WIMPs as a function of the WIMP mass.

FIRST RESULTS AND PROSPECTS

In 2008, a fiducial exposure of 18.3 kg.days was achieved using two 400g ID detectors. Fig. 4 shows that no nuclear recoils were observed, and this was interpreted in terms of limits for spin-independent scattering cross-section for WIMPs, as a function of their mass. This limit is comparable to what has been obtained with the exposure of 93 kg.days of detectors without active rejection : this demonstrates the importance of active surface event rejection.

The EDELWEISS collaboration is presently operating ten 400g ID detectors in its low-background facility at the LSM. A sensitivity of 4×10^8 pb should be reached by 2010. Further improvements will come from detector design enhancements, such as the development of detectors called FID for which the interleaved sets of rings are extended over the whole surface inducing an important increase of fiducial volume. On a longer timescale, ID detectors are well-fitted for future larger scale experiments (100 kg to 1 ton) for direct detection of WIMPs with bolometers, such as the EURECA [5] collaboration which federates the different teams developping cryogenic detectors in Europe.

REFERENCES

1. A. Juillard, J. Low Temp Phys (2008) 151: 806. Proceedings of the 12th LTD Workshop 2007.
2. X. Defay et al, J. Low Temp Phys (2008) 151: 896. Proceedings of the 12th LTD Workshop Paris 2007.
3. A. Broniatowski et al, J. Low Temp Phys (2008) 151: 830. Proceedings of the 12th LTD Workshop Paris 2007.
4. A. Broniatowski et al., submitted to PLB [arXiv:0905.0753].
5. H. Kraus et al., J. Phys. Conf. Ser. 39 (2006) 139.