EDELWEISS-II DARK MATTER SEARCH: STATUS AND FIRST RESULTS

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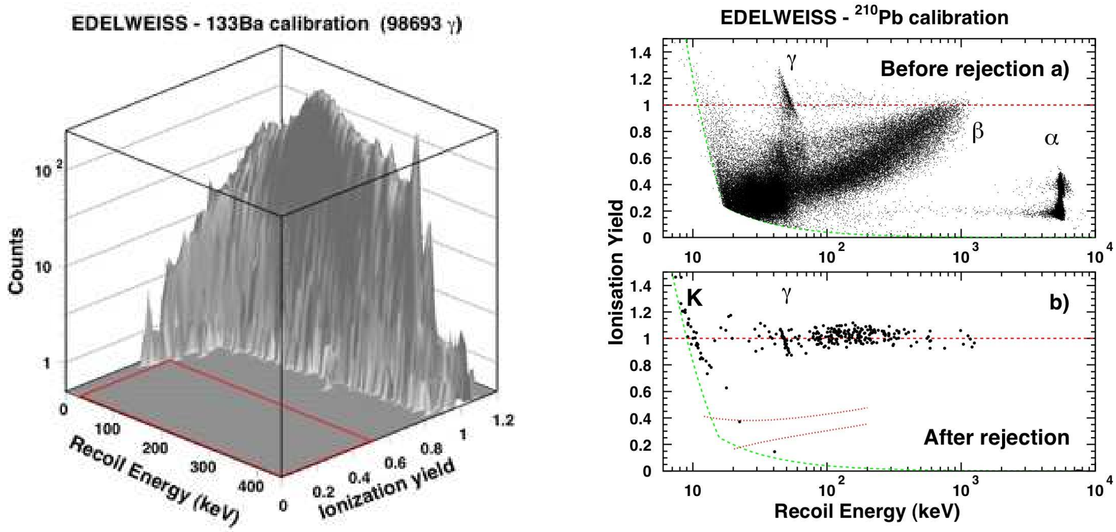
The EDELWEISS II experiment is devoted to the search for the Weakly Interactive Massive Particles (WIMP) that would constitute the Dark Matter halo of our Galaxy. For this purpose, the experiment uses cryogenic germanium detectors, cooled down at 20 mK, in which the collision of a WIMP with an atom produces characteristic signals in terms of ionization and elevation of temperature. We will present the preliminary results of the first operation of the detectors installed in the underground laboratory of the Frejus Tunnel (LSM), attesting to the very low radioactive background conditions achieved so far. Novel detectors, with a special electrode design for active rejection of surface events, have been shown to be suited for searches of WIMPs with scattering cross-sections on nucleon well below 10^{-8} pb. Preliminary results of WIMP search performed with a first set of these detectors will be shown as well..

1 Introduction

First indications for the existence of Dark Matter were already found in the 1930s[1]. By now there is strong evidence[2] to believe that a large fraction (more than 80%) of all matter in the Universe is Dark (interacts very weakly with electromagnetic radiation, if at all (no photon coupling)) and that this Dark Matter is predominantly non-baryonic. Weakly Interacting Massive Particles (WIMPs) are one of the leading candidates for Dark Matter. WIMPs are stable particles for which possible candidates arise in several extensions of the Standard Model of electroweak interactions[3]. Typically they are presumed to have masses between few tens and few hundreds of GeV/c^2 and a scattering cross section with a nucleon below 10^{-6} pb.

2 The EDELWEISS experiment

The EDELWEISS experiment (Expérience pour Détecter les WIMPs en Site Souterrain) is dedicated to the direct detection of WIMPs. The direct detection principle consists in the measurement of the energy released by nuclear recoils produced in an ordinary matter target by the elastic collision of a WIMP from the Galactic halo. The main challenge in the discrimination



(a) (b)

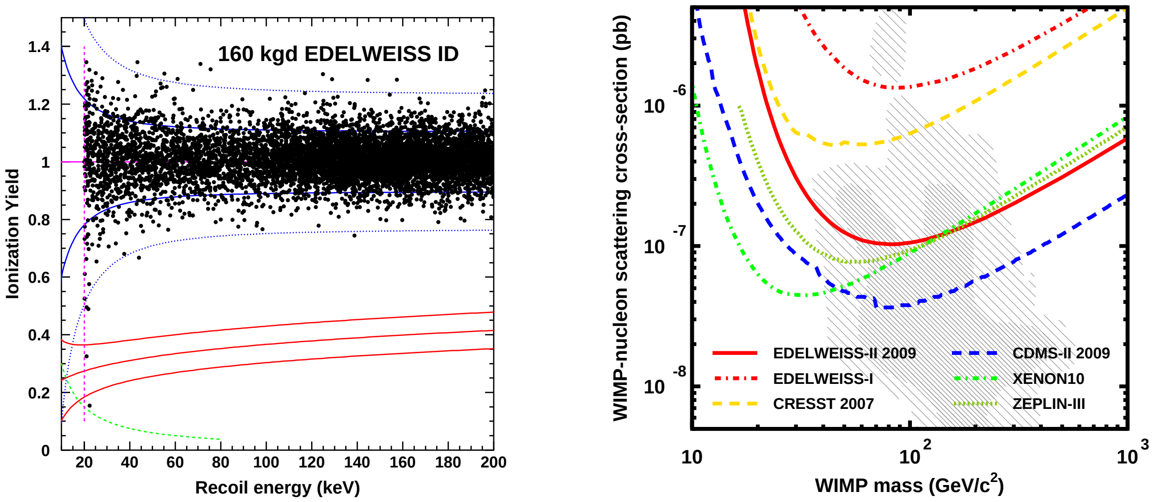
Figure 1: (a) ID detectors calibration with γ-rays from ^{133}Ba sources, no event is present in the region with a quenching factor lower than 0.5 where the WIMP signal is expected. (b) Ionization yield as a function of recoil energy recorded in ID detector during a ^{210}Pb source calibration. The comparison between panel (a) and (b) shows the high efficiency of surface event rejection on the population of α, β particles and near-surface γ rays from the source.

of these rare events from natural radioactivity is the expected extremely low event rate ($\leq$ 1evt/kg/year) due to the very small interaction cross section of WIMP with the ordinary matter. An other constraint is the relatively small deposited energy ($\leq$ 100keV). In order to measure low energy recoils, EDELWEISS employs cryogenic detectors (high purity Ge crystal) working at temperature of about 20 mK, with simultaneous measurements of phonon and ionization signal. The ionization signal, corresponding to the collection on electrodes of electron-hole pairs created by the energy loss process, depends on the particle type whereas the heat signal reflects the total energy deposit. This simultaneous measurements of two signals allows an event by event discrimination between the electronic recoils, tracers of electromagnetic background (induced by photons and electrons) and the nuclear one originated by neutrons and WIMPs.

The first protection against background is provided by the choice of the location: the experiment is situated in the Modane Underground Laboratory (LSM) in the Fréjus highway tunnel, where an overburden corresponding to ~4850 mwe (meter water equivalent) reduces the cosmic muon flux down to 4.5 μ/m^2/day, that is about 10^6 times less than at the surface.

The main limiting background of the experiment comes from interactions occurring just underneath the collecting electrodes: essentially low energy β-rays due to ^{210}Pb contamination of the detector surface and/or in the vicinity of the detectors [5]. The incomplete charge collection of these events can mimic nuclear recoils.

Specific improvements are aimed at the active rejection of surface events: the electrodes on the flat surfaces of the detectors are replaced by concentric, annular interleaved electrodes (Ge-InterDigit detector). With this ID detectors, surface events are tagged by the presence of charge on two electrodes on the same side of the detector. The phonon measurement is provided by a simple GeNTD thermistance, glued to the detector. This method is very efficient to reject surface interaction, as shown in Fig. 2. It shows the ionization yield as a function energy of events recorded for calibration performed with a ^{133}Ba source (1a) and a ^{210}Pb source (1b). For the beta calibration, one event is present after the fiducial selection in the nuclear recoil region where the WIMP signal is expected (1b) and none for the gamma calibration (1a).



(a) (b)

Figure 2: (a) Ionization yield vs recoil energy of fiducial events recorded in an exposure of 160 kg·d. The WIMP search region is defined by recoil energies above 20 keV (vertical dashed line). The 90% acceptance nuclear and electron recoils band (full red and blue lines, respectively) and the 99.98% acceptance band for γ are also plotted. The dashed green line represents a 3 keV ionization threshold. (b) Limits on the cross-section for spin-independent scattering of WIMPs on nucleons as a function of WIMP mass, from other direct WIMP searches and from the data presented here.

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 60 keV. Such performances, detailed in [12], are required to achieve spin-independent WIMP sensitivities below 10^{-8} pb.

In the six-month run, nine of ten ID detectors have taken into account for a WIMP search analysis[13]. After all quality cuts, they result in a total exposure of 876.7 detector-days. The 2008 data with two of these nine ID detectors provides an additional exposure of 122.3 detector-days.

With the average fiducial mass of 160 g, this corresponds to a total of 160 kg·d. Finally, taking into account the 90% C.L. region for nuclear recoils, this data set is equivalent to 144 kg·d with an acceptance of 92% at 20 keV. Fig. 2a shows the distribution of Q as a function of recoil energy for the entire exposure. One event is observed in the nuclear recoil band at 21.1 keV. This represents a factor ∼50 reduction relative to the event rate above 20 keV measured in EDELWEISS-I. The upper limits on the WIMP-nucleon spin-independent cross-section correspond to a value of 1.0×10^{-7} pb at 90%CL for a WIMP mass of 80 GeV/c^2 .

The presented analysis results in more than one order of magnitude improvement in sensitivity compared with the previous EDELWEISS results[6] based on detectors without surface event identification. The sensitivity can be further improved by an increase of exposure, additional detectors installed in the EDELWEISS-II cryostat, and of fiducial mass, R&D project for bigger ID detectors (FID).

3 Conclusions and perspectives

The EDELWEISS II collaboration has performed a direct search for WIMP dark matter using nine 400 g heat-and-ionization cryogenic detectors equipped with interleaved electrodes for the rejection of near-surface events. A total effective exposure of 144 kg·d has been obtained after six months of operation in 2009 and additional data from earlier runs with two detectors in 2008. The observation of one nuclear recoil candidate above 20 keV is interpreted in terms of limits on the cross-section of spin-independent interactions of WIMPs and nucleons. Cross-sections of 1.0×10^{-7} pb are excluded at 90%CL for WIMP masses of 80 GeV/c^2 . Further analysis are going on in order to reduce the effective threshold of the detectors to better address the case of lower-mass WIMPs. This result demonstrates for the first time the very high rejection capabilities of these simple and robust detectors in an actual WIMP search experiment. It also establishes the ability of the EDELWEISS-II experiment for long and stable low-radioactivity data taking and for the rejection of neutron-induced nuclear recoils. Provided the surface event rejection is efficient enough, the combination of fiducial mass to be installed and neutron screning/rejection should enable to reach sensitivities at the level $\sim$ few 10^{-9} pb in the coming years.

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