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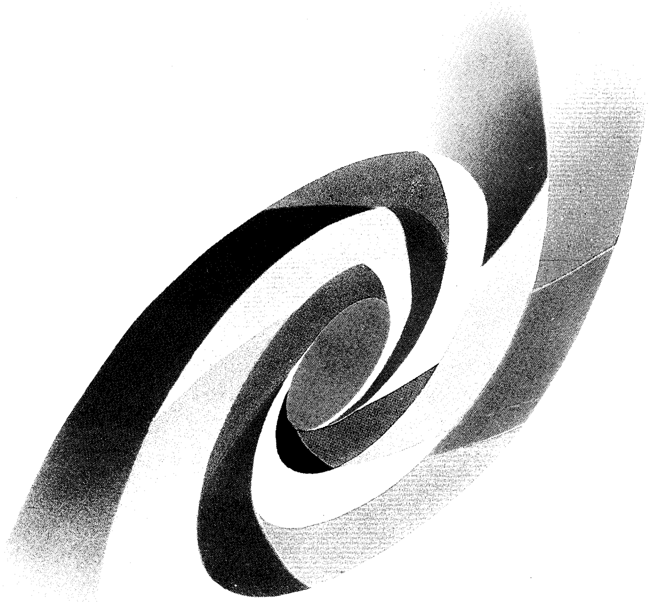

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DARK MATTER SEARCH IN THE EDELWEISS EXPERIMENT USING A 230 g IONIZATION-HEAT Ge-DETECTOR

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(For the EDELWEISS Collaboration)

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Dark Matter search in the EDELWEISS Experiment using a 320 g Ionization-Heat Ge-Detector

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Abstract. The EDELWEISS collaboration has performed a direct search for WIMPs using a 320g ionization-heat Ge-cryogenic detector operated in a low-background environment in the Laboratoire Souterrain de Modane. No nuclear recoils events are observed in the fiducial volume in the 30-200 keV energy range during an effective exposure of 4.53 kg.days. A limit on the cross-section of the WIMP-proton spin-independent interaction as a function of the WIMP mass is deduced. The central value of the signal reported by the DAMA experiment is excluded at 90% CL.

1-INTRODUCTION

EDELWEISS is a direct detection experiment searching for WIMPs of the Galactic halo. The experiment is set in the Modane Underground Laboratory under the Alps where the muon background flux reduces to $4.5/m^2/day$ and the neutron flux ($\approx 2\ 10^{-6}/cm^2/s$ in the 2-10 MeV range) is mainly due to nuclear reactions in the rock[1]. A description of the experimental setup can be found in Ref. 2.

EDELWEISS has developed cryogenic germanium detectors, which are measuring ionization and heat simultaneously[3,4]. The motivation for developing cryogenic detectors lies in the possibility to improve the energy threshold and resolution compared to classical detectors. Furthermore, while the present experiments are mostly limited by the radioactive background and by systematic uncertainties[5,6,7], the simultaneous measurement of ionization and heat[8] (or scintillation and heat[9]) allows a much more reliable discrimination between the electron recoils produced by the radioactive background and the nuclear recoils expected from WIMP interactions. In the following, we report on the first results obtained with the first 320g ionization-heat detector.

2- THE 320G IONIZATION-HEAT DETECTOR

The detector[3] is a cylindrical Ge crystal (70 mm diameter and 20 mm thickness) with Al electrodes for ionization measurements. The top electrode is divided in a central part and a guard ring, electrically decoupled for radial localization of the charge deposition. A fiducial volume, defined by selecting events for which more than 75% of the charge is collected in the center electrode[4,10], is determined by neutron and gamma calibrations and is found to be 54 ± 2 (stat.) ± 5 (syst.) % of the total detector volume. During data taking, a voltage V_o = 6.37 V was applied between the two top and the bottom electrodes.

The heat and ionization responses to γ rays were calibrated using ^{57}Co and ^{60}Co sources. Over the entire data-taking period, the baseline resolutions on the center and guard ring ionization signals were better than 2.0 keV FWHM, and varied between 1.9 and 3.5 keV FWHM for the heat signal. The corresponding resolutions measured at 122 keV are approximately 3, 2 and 3.5 keV FWHM, for the center, guard ring and heat signals respectively. The ionization resolution was limited by microphonic noise. The trigger efficiency is close to 50% at 5.7 keV and approximately 100% at 8 keV.

The detector is mounted in a dilution cryostat shielded from the radioactive environment by 10 cm of copper and 15 cm of lead[2]. Pure nitrogen gas is circulated around the cryostat in order to reduce radon accumulation. All materials in the close vicinity of the detectors were selected after measuring their radioactivity. Moreover, all electronic components were moved away from the detector and hidden behind a 7 cm thick archeological lead shield. The entire setup is surrounded by a 30cm thick paraffin shielding against neutrons. Taking into account this shield configuration, and using Monte-Carlo simulations, residual nuclear recoils above 30 keV due to neutrons are expected to be of the order of 0.03 per kg and per day.

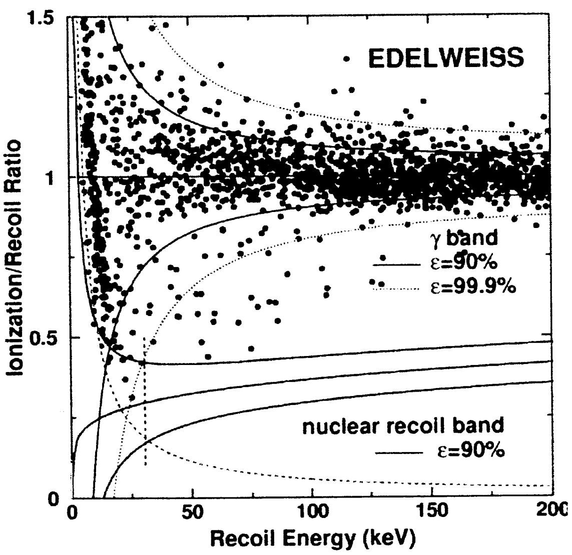
3- RESULTS AND PERSPECTIVES

We present here the results obtained in a physics data taking of 9.31 kg.days and a effective exposure of 4.53 kg.days (5.03 kg.days with an efficiency of 90%).

Figure 1A shows the distribution of the quenching factor as a function of the recoil energy from the data collected in the center fiducial volume of our 320 g detector. Most events are within the 99.9% efficiency photon band. A few events lie between this region and the nuclear recoil band. They are interpreted as surface events with reduced charge collection[4]. No nuclear recoils are observed in the fiducial volume in the 30-200 keV energy range during this exposure.

Figure 1B shows the histogram of the quenching factor. A comparison of the results of the present 320 g detector with the previous results obtained with a 70 g detector[4,11] shows a significant improvement, which correspond to a factor ≈ 50 in the exclusion plot limit (see below). Part of these improvements comes from the decrease of radioactive backgrounds in the close vicinity of the detector and from the rejection of edge events by the guard electrode. On the other hand, the Al-sputtered electrodes appear to reduce the incomplete charge collection for surface events, which severely limited our previous detector performances.

A conservative exclusion limit on the spin independent cross section versus WIMP mass diagram has been extracted from these data without any neutron background subtraction (cf. Figure 2).



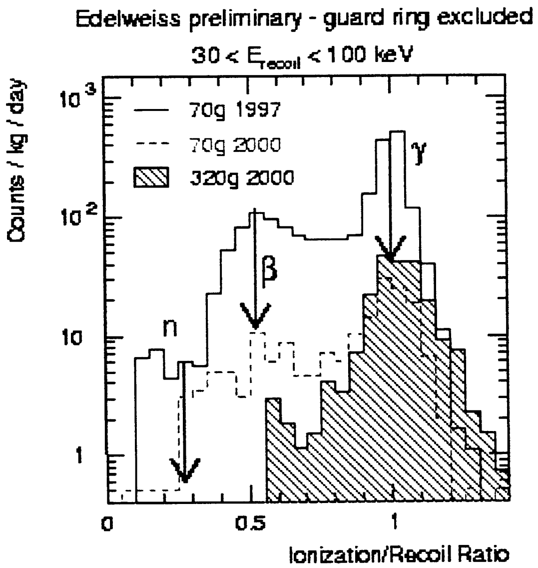


FIGURE 1A. Distribution of the quenching factor (ratio of the ionization energy to the recoil energy normalized to 1 for electron recoils) as a function of the recoil energy from the data collected in the center fiducial volume of the 320 g EDELWEISS detector. The exposure of the fiducial volume corresponds to 5.03 kg.days. Also plotted are the $\pm$ 1.645 σ bands (90% efficiency) for photons and for nuclear recoils. The 99.9% efficiency region for photons is also shown (dotted line). The hyperbolic dashed curve corresponds to 5.7 keV ionization energy and the vertical dashed line to 30 keV recoil energy.

FIGURE 1B. Histogram of the quenching factor for events with recoil energies between 30 and 100 keV. The quenching factor has been normalized to 1 for electron recoils. The quenching factor is expected to be approximately 0.3 and 0.5 for nuclear recoils and surface electron recoils, respectively.

The EDELWEISS collaboration has searched for WIMP induced nuclear recoils using a 320 g heat-and-ionization Ge detector operated in a low-background environment in the Laboratoire Souterrain de Modane. After an effective exposure of 4.53 kg.days, the rate of Ge recoils with kinetic energies between 30 and 200 keV is measured to be less than 0.51 per kg.day at 90% CL. This is the most stringent limit based on the observation of zero event and not relying on any statistical background subtraction. These EDELWEISS results exclude at more than 90% CL the central value of the DAMA region[6] (52 GeV/c^2 WIMP with an interaction cross-section of 7.2 10^{-6} pb). With a four-fold increase of exposure time or with some improvements in the detector resolution, the sensitivity of the present detector should be able to test the whole parameter space of the DAMA candidate. In a forthcoming run, we will install three new 320g detectors[10]. We expect to start the data taking with this 1kg total mass in autumn 2001. A larger set-up with 21 (and then 100) 320g improved detectors in a new 100 liters cryostat is also in preparation.

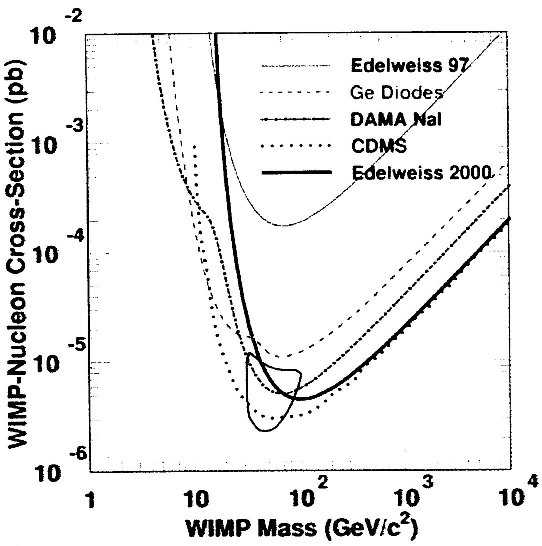


FIGURE 3. Spin-independent exclusion limit (dark solid curve) obtained in this work. Thin solid curve: EDELWEISS 1997 result[11]. Dashed curve: combined Ge diodes limit[5]. Dash-dotted curve: DAMA NaI limit using pulse-shape discrimination[6]. Dotted curve: CDMS limit with statistical subtraction of the neutron background[12]. Closed contour: allowed region at 3 σ CL for a WIMP r.m.s. velocity of 270 km/s claimed by the DAMA experiment[6].

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