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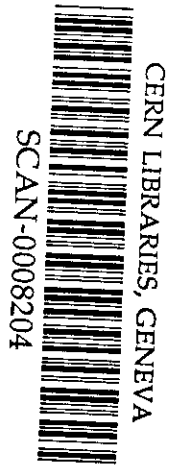
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Status of the EDELWEISS experiment

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Status of the EDELWEISS experiment

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Abstract. The Edelweiss Dark Matter Experiment is installed in the Modane Underground Laboratory since 1994. In 1997 the first detector of a 70 g heat and ionization Ge low-temperature detector built by the collaboration showed its discrimination capabilities. During the last two years the installation was upgraded, and a new generation of 70 g Ge detectors is operational. The detector environment is drastically controlled to avoid radioactive contamination. A test run with two new 70 g detectors shows a reduction by a factor of ten in the background level before γ -ray rejection which is now around 2 events/kg/keV/day. Three 320 g Ge cryogenic detectors have been constructed and are now being tested and should soon be operational in the present cryostat. A new cryostat is being built and will allow a detection volume of 100 l. It is expected to be installed in Modane next year. In a first step of 21x320 g Ge detectors, the Edelweiss-II experiment should test an important fraction of the MSSM Susy parameter space.

1 Introduction

Edelweiss (Expérience pour DEtecter Les WIMPs en Site Souterrain) is a dark matter experiment dedicated to the direct detection of WIMPs. It is installed since October 1994 in the Underground Laboratory of Modane in the Fréjus highway tunnel under the Alps at the French-Italian border (Fig. 1). The mountain above the laboratory offers a 1780 m rock coverage reducing the muon flux to 4 muons/m²/day. The fast neutron flux is $(4.0 \pm 1.0) \times 10^{-6}$ neut/s/cm² [1].

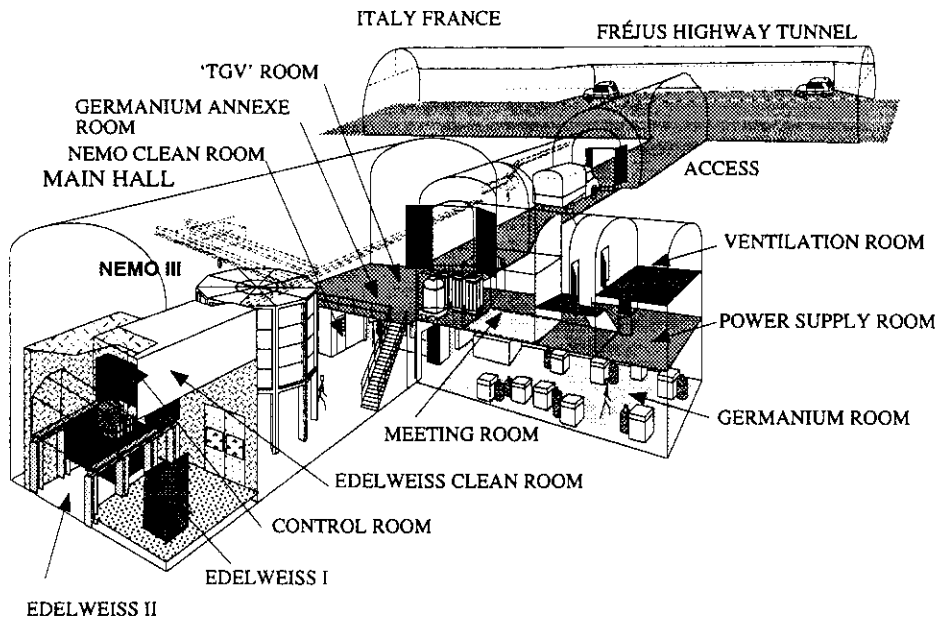


Fig. 1. The Underground Laboratory of Modane.

2 Edelweiss-I:

2.1 The 70 g Ge detector performances

Among the possible WIMP detection methods the Edelweiss collaboration decided to develop cryogenic detectors allowing the simultaneous detection of both charge and heat signals resulting from a particle interaction (Fig. 2). This technique permits the discrimination between electron recoils produced by the radioactive background and the nuclear recoils expected from WIMP interactions. The first detector built by the collaboration is a 70 g germanium bolometer which reached in July 1997 very good sensitivity levels comparable to the best experiments. The detailed performances of this detector are described elsewhere [2-4].

Its performances are essentially limited by the relatively high radioactivity level in its environment.

Despite the efforts made to reduce the background an embarrassing residual population of off-axis events persists. This population can be classified into two different categories interpreted as electron and nuclear interactions occurring close to the surface of the detector, whereas the two classes of main-axis events correspond respectively to electron and nuclear recoils in the volume of the detector. A detailed analysis of these events is given elsewhere [5,6], see also Fig. 4

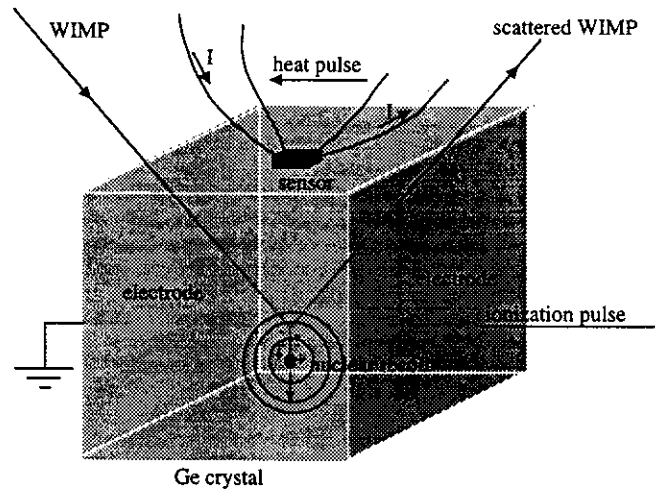


Fig. 2. Basic principle of a heat-ionization Ge cryogenic detector

A new generation of detectors, with new electrode implantation schemes is currently being tested in the LSM.

Considerable efforts have been made in the detector environment to reduce the radioactive background: nitrogen flushing for radon removal, Roman lead shielding close to the detector, 30 cm thick paraffin shielding against neutrons. Runs with a new 70g Ge detector show a background level of ≈ 2 evt/keV/kg/d below 50 keV, before gamma-ray rejection, a factor of 10 improvement over previous data (Fig. 3). 1.97 kg.d of data have been accumulated (at a bias voltage of -6V) leading to a preliminary event rate of 0.25 evt/keV/kg/day at 90% CL over the 20 - 100 keV recoil energy interval.

2.2 Neutron background

The fast neutron background in the LSM is mainly produced by the natural radioactivity from the rock; it was measured by V. Chazal et al. [1]. The neutron energy distribution above 1 MeV (detector threshold) is concentrated around 3 MeV.

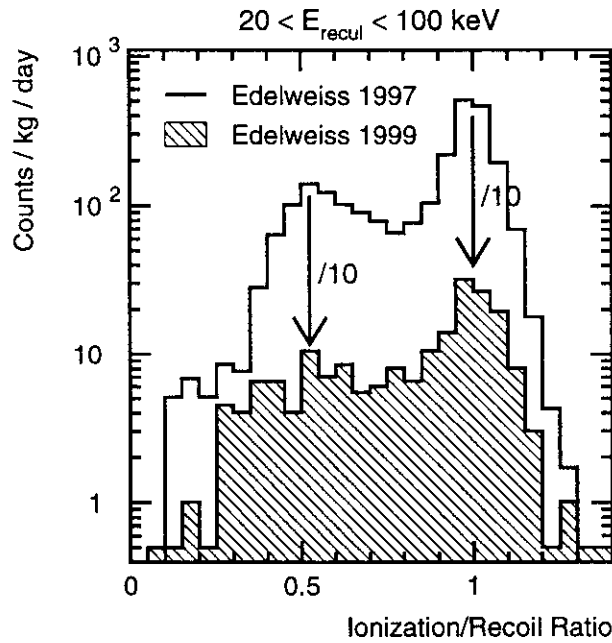


Fig. 3. Comparison between 97 and 99 data obtained with 2 different 70 g Ge detectors.

The spectrum represented in Figure 5 was obtained by simulating the neutrons produced by 30 cm of rock surrounding the LSM. The neutron simulation program is based on the GEANT 3.21 program [7] modified by de Kerret et al. [8] to track individual neutrons with a kinetic energy below 10 MeV.

The simulated neutron nuclear recoil spectrum induced in a 70 g Ge detector and the experimental points (without paraffin shielding) are represented in Figure 6 which shows a rough agreement between the simulation and the measurement for the first detector. A recent and preliminary test run with the 30 cm thick paraffin shielding gives a smaller reduction factor in the rate than the expected two orders of magnitude. This result implies that the events in the nuclear recoil zone in the case of the new 70 g Ge detector are probably mainly due to the population of off-axis events mentioned in the previous section.

2.3 SICANE: Ge heat quenching factor

The heat quenching factor for cryogenic detectors is supposed to be one, but very little work has been done to verify this statement [9,10]. Edelweiss has built an experimental set ((Site For the CALibration with NEutrons) in order to measure the quenching factor describing the heat generated in a Ge crystal by nuclear recoils produced by the scattering of neutrons of known initial and final energies.

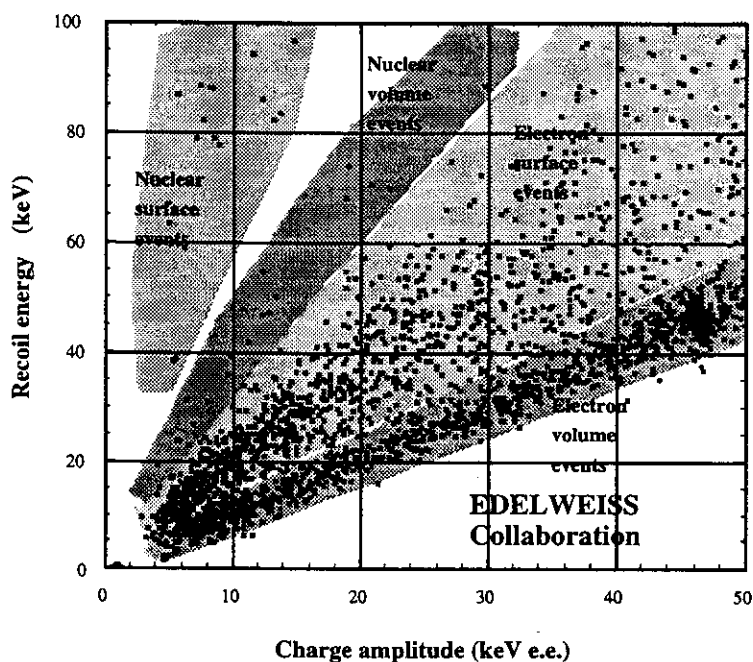


Fig. 4. Scatter diagram of the recoil energy versus charge amplitude for a 70 g Ge detector resulting from a 1.17 kg.day background measurement. The scatter diagram exhibits four populations of events attributed to volume electron recoils, surface electron recoils, volume nuclear recoils, surface nuclear recoils [5]

An array of 47 NE213 neutron detectors is used. Neutron detectors are distributed in four rings corresponding to neutron scattering angles of 45° , 90° , 120° and 165° . In a first step a NaI(Tl) crystal was used to test the installation. Neutron scattering events were selected using the timing of the signal in the NaI(Tl) relative to the beam bursts, the time-of-flight between the NaI(Tl) and neutron detectors, and the neutron-gamma discrimination of the NE213 detectors. The measurements were found to be compatible with those of a previous experiment [11] performed at the Bruyeres-le-Chatel tandem with a reduced set-up, and with the predictions of the Birks model [12].

In the second step a cryostat was installed at the center of the array. The cryostat has to be suspended at a height of 1.8 m above ground in front of the beam line. The measurement of the heat quenching factor of Ge was performed last February. As a first consistency check, a quenching factor for the ionization process was extracted from the data, and was found to be compatible with those of [13]. The analysis to extract the heat quenching factor for Ge is in progress.

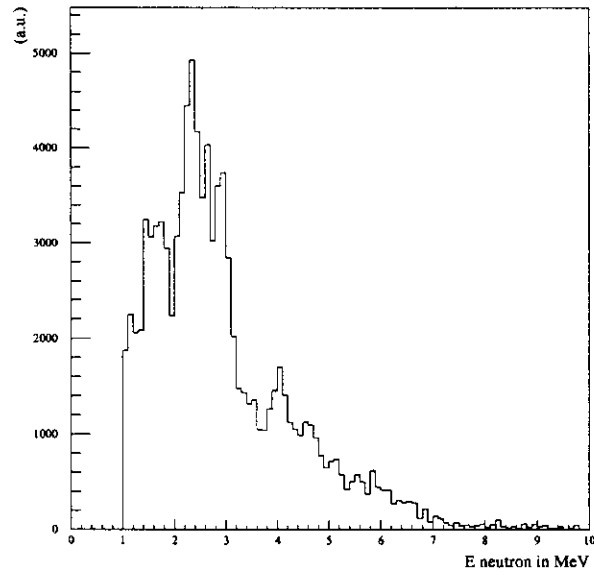


Fig. 5. Fast neutron background spectrum in the Underground Laboratory of Modane[1]. The sharp drop at $E = 1$ MeV is due to the detector threshold.

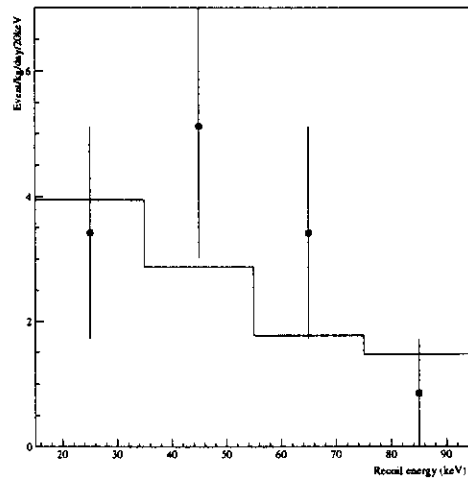


Fig. 6. Experimental nuclear recoil spectrum (filled circles) obtained in 97 with a 70 g Ge detector. The histogram is a neutron simulation of the fast neutron background spectrum in the LSM.

2.4 The "1 kg" stage

The next step, the so called "1 kg" stage, will be the installation of three 320 g Ge bolometers [14] in the Edelweiss-I cryostat in Modane. Due to the small size of the detection volume a part of the close Roman lead shielding will be removed. The three detectors will be closely packed in order to shield each other, and to use the possible veto-coincidence. The central detector is equipped with an annular outer segmented electrode allowing the suppression of the incomplete charge surface events. Finally assuming the 320 g detectors will have the same rejection performances as the 70 g [4] the event rate would be 0.3 evt/kg/d in the energy range 20 - 100 keV before the end of this year. The present limits and the Edelweiss 2000 goal are represented in the exclusion plots in Fig. ?? for the spin-independent interaction.

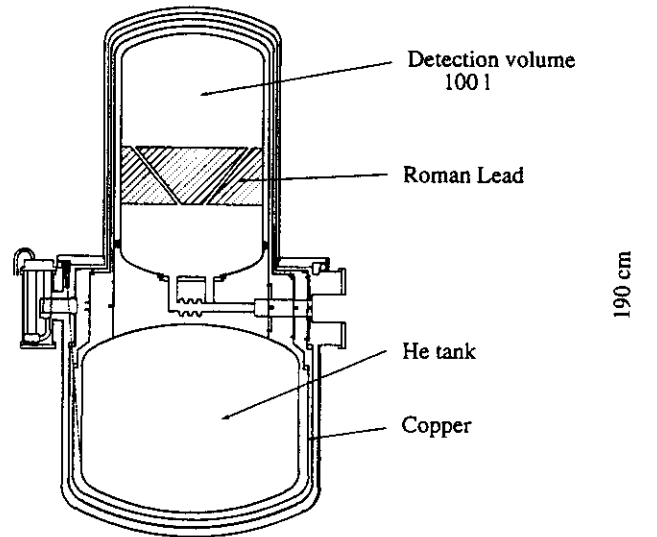


Fig. 7. New cryostat for the Edelweiss-II stage

3 Edelweiss-II :

A new cryostat (Fig. 7) with a detection volume of 100 l is being built. It will be installed in the LSM next year. In the meantime 21x320g detectors will be built and tested in order to be installed in the new cryostat.

The collaboration is also working on the development of cryogenic detectors using germanium crystals as absorbers and amorphous Nb_xSi_{1-x} thin films as thermometers [15-17]. This technique gives access to ballistic phonons and thus to the possibility of surface event localisation.

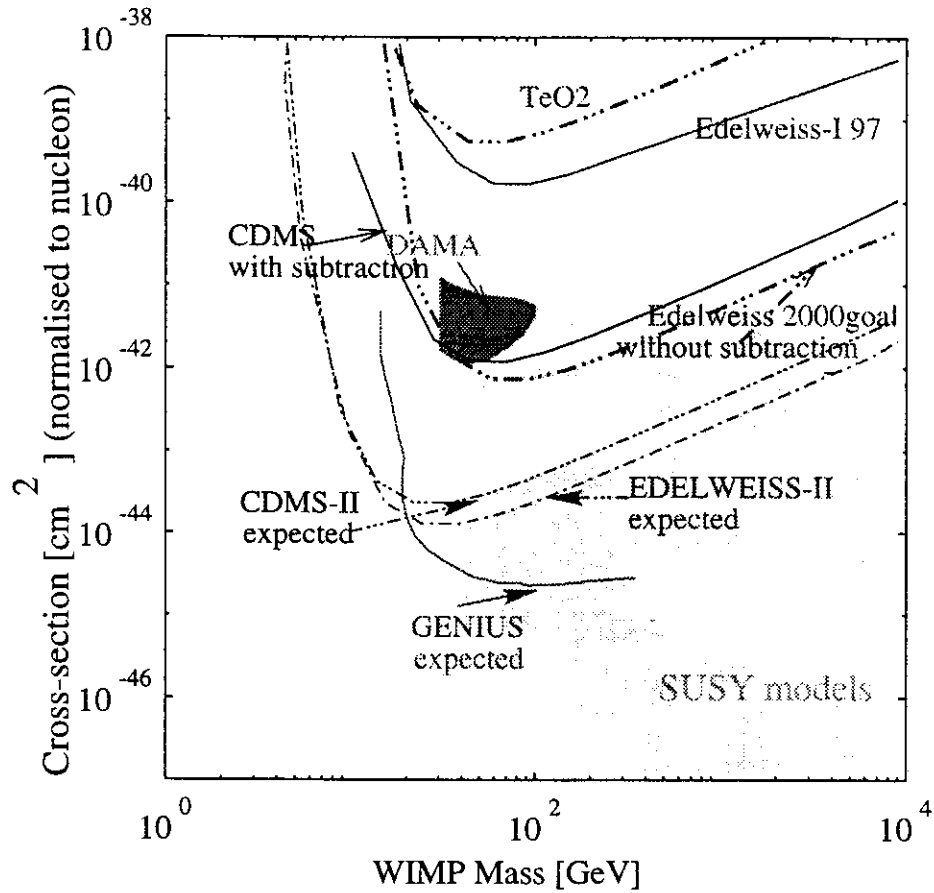


Fig. 8. Present results for the Milano group (TeO₂ [10]), Edelweiss 1997, CDMS [18] and the DAMA 3σ allowed region [19]. Sensitivity goals for Edelweiss 2000, Edelweiss-II, CDMS-II [18], and GENIUS [20]. The shaded zones are Susy models [21]

With the new cryostat, 2500 kg.days Ge, a neutron paraffin shielding of 50 cm thickness, and a reduction of the raw rate, our goal is to reach $2 \cdot 10^{-4}$ evts/kg/keV/day after the background rejection in the recoil energy interval 5 - 20 keV. This is comparable to the CDMS projection [18] in the exclusion plot (Fig. 8). A significant part of the supersymmetric models for dark matter will then be probed.

4 Conclusion

In 97 the discrimination capabilities of a 70 g heat and ionisation Ge bolometer in an underground environment were demonstrated. Since then several improvements have been made reducing the overall background (before γ rejection) to

2 evt/keV/kg/day in the recoil energy interval 15 - 45 keV. Our efforts are now concentrated on the understanding and suppression of the surface event populations. This is essential for the next generation of 320 g Ge detectors. A large cryostat will be operational next year in the LSM and a few months of data taking with 21x320 g Ge bolometers should allow the test of a significant part of the susy parameter space.

5 Acknowledgment

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