Eur Phys J C **33**, s01, s965–s967 (2004)
Digital Object Identifier (DOI) 10.1140/epjcd/s2004-03-1753-x

EPJ C direct
electronic only

Latest results from the EDELWEISS experiment

L. Chabert, for the EDELWEISS collaboration [1]

IPNL, 4 rue Enrico Fermi, 69622 Villeurbanne, France, e-mail: `chabert@ipnl.in2p3.fr`

Received: 17 October 2003 / Accepted: 20 January 2004 /

Abstract. The latest results obtained by the EDELWEISS experiment using three heat-and-ionisation 320 g germanium bolometers are presented. EDELWEISS is presently the most sensitive WIMP direct detection experiment for all WIMP mass compatible with accelerator constraints. The status and main characteristics of the EDELWEISS-II setup, involving in a first stage 28 germanium bolometers, and able to accommodate more than 100 detectors, are presented.

PACS. 95.35.+d – 14.80.Ly – 98.80.Es – 29.40.Wk – 95.85.Ry

1 Introduction

Astronomical observations [2] indicate that most of the matter in the Universe is dark and non baryonic. The EDELWEISS experiment is devoted to the search for the cold dark matter component which could be made up of Weakly Interacting Massive Particles (WIMPs) with a mass between a few tens and a few hundreds of GeV/c^2. In the Minimal SuperSymmetric Model (MSSM) framework, a WIMP candidate is the LSP (Lightest Supersymmetric Particle) which corresponds to the neutralino, linear combination of the supersymmetric partners of the Z^0, photon, and neutral Higgs bosons.

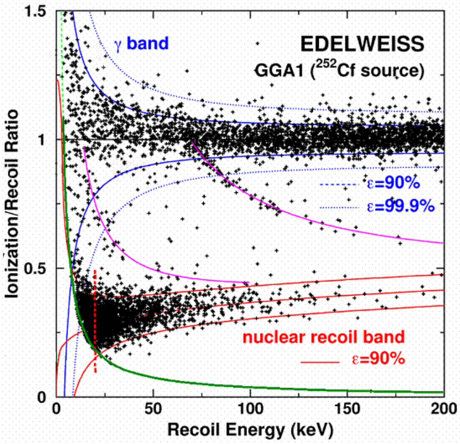

Fig. 1. Distribution of the ratio of the ionisation signal to the recoil energy (defined as the parameter Q) as a function of the recoil energy collected using a ^{252}Cf source. Also plotted are the $\pm 1.645\sigma$ bands corresponding to 90% efficiency and defining the electron and nuclear recoil zone. The two hyperbolae, intersecting the γ ray line at 13.26 keV and 68.75 keV, correspond to inelastic interactions

2 Direct detection in EDELWEISS

Direct detection experiments (for example: CRESST[3], DAMA[4], CDMS[5], IGEX[6] and ZEPLIN[7]) search for WIMP interactions in a detector (elastic scattering on a nucleus), and are complementary to indirect detection experiments that search for annihililation products of WIMP (for example see: AMANDA[8], ANTARES[9]). Because of the low event rate expected in the detectors ($\ll$ 1 evt/kg/d), the EDELWEISS experiment is set in the Laboratoire Souterrain de Modane (LSM), adjacent to the Fréjus highway tunnel connecting France to Italy, and under $\sim$ 1700 m of rock. The neutron[1] flux in the LSM, is about 1.6×10^{-6} n/cm^2/s mainly from the surrounding rock and concrete radioactivity. The rock overburden reduces the muon background flux by a factor $\sim$2.10^6 (and measured to be $\sim$ 4.2 μ/m^2/d [10] after attenuation). To further ensure a low background environment, passive shielding surround the experiment. A 30 cm thick paraffin shielding reduces by a factor 100 the fast neutron flux ($E_n \gtrsim 1$ MeV). In addition, we place copper and lead shields to reduce the gamma background.

The EDELWEISS experiment has developed cryogenic germanium detectors (T$\sim$17 mK) with simultaneous measurements of charge and phonon signals [11]. The heat measurement is obtained using a NTD sensor. Such detectors are sensitive to the $\sim$10μK temperature increase produced by the heat generated by the Ge nucleus recoil energy. Furthermore, Ge crystals are equipped with aluminium electrodes for the collection of the electron-hole pairs.

Measurement of both signals allows an excellent event-by-event discrimination between the main sources of radioactive background (γ, β producing electron recoils) and

---

[1] which gives a spectrum in a Ge detector similar to a WIMP

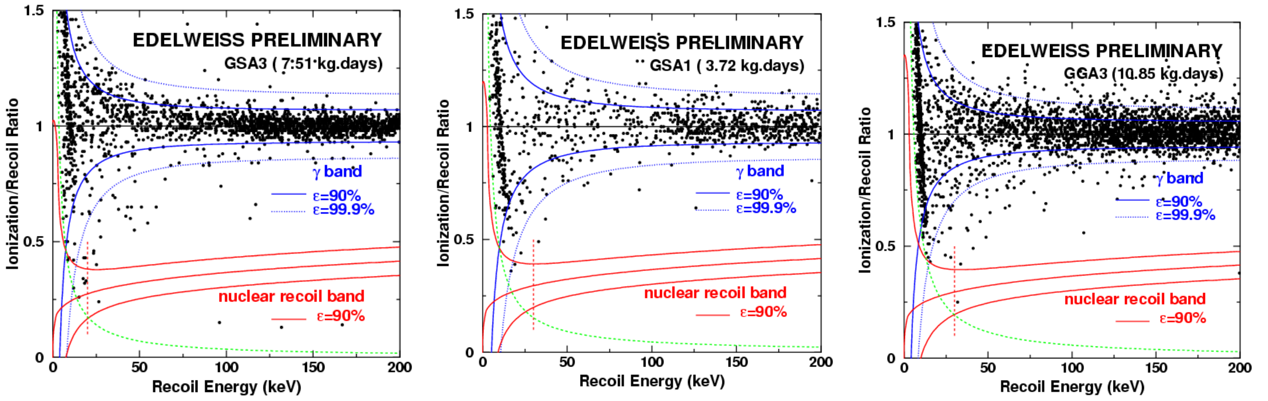

Fig. 2. Quenching factor versus recoil energy diagrams Q=f(E_r) from the data collected in the center fiducial volume of the three EDELWEISS detectors GSA3, GSA1 and GGA3

the nuclear recoils expected from WIMPs and neutron interactions, because of the different ionisation/heat ratios for electron recoils and nuclear recoils. The discrimination performances shown in Fig. 1 are obtained with a 320 g heat-ionisation detector (with Ge amorphous layer) during a neutron calibration. The recoil energy threshold using ionisation triggering is 20 keV or 30 keV depending on the detector (>99% trigger efficiency). A rejection factor of the electron recoils >99.9% is measured during gamma-ray calibrations (^{60}Co and ^{137}Cs).

3 The 1-kg stage of EDELWEISS I

Results have been already published, obtained with one 320g germanium bolometer [1] with Ge amorphous layers. EDELWEISS-I uses now three bolometers in the LSM with the same technology as described above, except the Si amorphous layers for two of the detectors (labeled GSA1 and GSA3) and Ge amorphous layers for the third one (GGA3). The preliminary results from the data taking between October 2002 and March 2003 are presented in the following. The ionisation baseline resolutions are all $\sim$ 1 keV FWHM and between 0.3 and 2 keV for the heat channels. The main features obtained for each bolometer are the following (Fig. 2):

- GSA3: 7.51 kg.d exposure in fiducial volume (defined as in [12]) and a recoil energy threshold of 20 keV.
- GSA1: 3.72 kg.d fiducial exposure (smaller exposure due to read-out electronic problems) and an energy threshold fixed to 30 keV.
- GGA3: 10.86 kg.d fiducial volume and the energy threshold is 30 keV.

In these data sets, three events are observed in the recoil zone between 20 and 200 keV recoil energy. One is at E_r $\sim$200 keV and is very unlikely to come from WIMP scattering for M_{WIMP} <1 TeV. This result is interpreted in terms of an upper limit at 90% CL on the WIMP-nucleon scattering cross-section in Fig. 3. The EDELWEISS new limit is calculated without a background subtraction and improves slightly our previous limit [1]. The influence of the halo model is discussed in [13]. Figure 4 presents a comparison with other direct detection experiments: EDELWEISS is the most sensitive experiment for a WIMP mass > 35 GeV among published results.

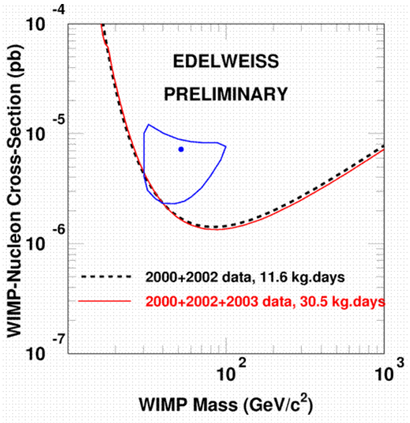

Fig. 3. The full line is the preliminary spin-independent exclusion limit from EDELWEISS obtained combining the new preliminary data and the previous one (*dashed curve*). *Closed contour:* allowed region at 3σ CL for a WIMP r.m.s velocity of 270 km/s from DAMA NaI1-4 annual modulation data [4]

To summarize, we have accumulated 20 kg.d additional data sample for an overall exposure of 13.8 kg.d @ 20 keV and 30.5 kg.d @ 30 keV. The > 99.9% CL incompatibility with DAMA candidate is confirmed with these three new detectors and the data taking is still going on.

4 Next step: EDELWEISS-II

To explore the parameter space of SUSY models, a large mass of detectors is required. Therefore, EDELWEISS is actively preparing a second stage of the experiment which could accommodate up to 120 detectors ($\sim$36 kg). A first stage of 28 detectors, composed by 21×320 g Ge-NTD detectors and 7×400g Ge detectors with NbSi thin film sensors, is approved. EDELWEISS-II will use a 100-liter dilution fridge, built in the CRTBT in Grenoble, using

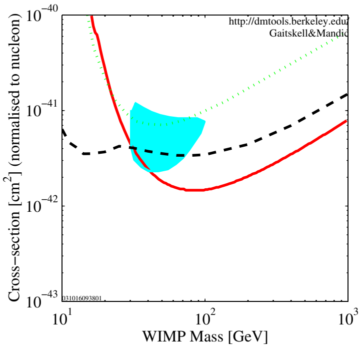

Fig. 4. Preliminary spin-independent exclusion limit (red/black *solid curve*) obtained with three 320 g bolometers and no background subtraction. *Dotted curve*: IGEX 2002 results [6]. *Dashed curve*: CDMS limit with backgound subtraction [5]. *Closed contour:* allowed region at 3σ CL from DAMA NaI1-4 annual modulation data [4]

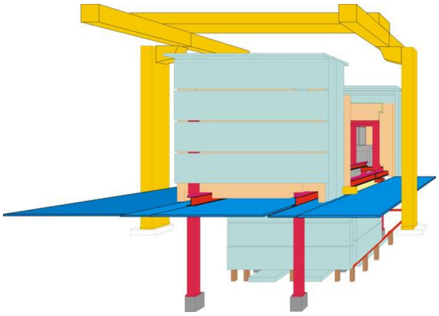

Fig. 5. EDELWEISS-II external shielding general view

a new reversed geometry more suited for handling detectors. This low radioactivity cryostat has reached a temperature of 10 mK during test runs and is now being commissionned. It will not use nitrogen and benefits from a He recondenser. In the coming year, the cryostat will be set in a clean-room at the LSM.

This second stage should provide a significant increase in sensitivity, from the current 0.2 event/kg/d, down to 0.002 event/kg/d with EDELWEISS-II. In order to achieve this expected rate, passive shieldings will surround the installation and will be made up of 50 cm polyethylen (neutron moderator) added to 20 cm of lead. A view of the planned EDELWEISS-II shields is shown on Fig. 5.

At such a sensitivity level, the knowledge of neutron production by high energy muons ($< E_\mu > \sim 300$ GeV at LSM [14]) interacting in the surrounding rock and inside EDELWEISS-II is crucial. Indeed, the rate of muon-induced neutrons is about 10^{-2} event/kg/d at detector level and represents the highest part of the expected background. To identify the neutrons induced by muons inside the lead shields, a muon veto is required. The muon veto, made of about 140 m^2 of plastic scintillators, is developed by FZ Karlsruhe. The geometrical efficiency of the veto system has been simulated using the measured angular-energy distributions of the muons entering the LSM[15]. The present configuration shown in Fig. 6 has a geometrical efficiency $> 99\%$.

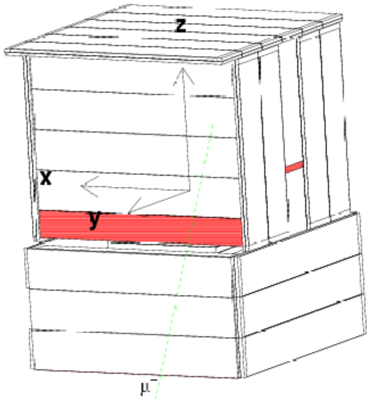

Fig. 6. Veto configuration used for the simulations (The holes are represented in red)

5 Conclusion

Preliminary results presented above confirm our previous spin-independent exclusion limit. Data taking with EDELWEISS-I will stop at the end of 2003 and the EDELWEISS-II installation will start early in 2004. With all the improvements, this second phase should be able to check a significant part of the supersymmetric parameter space during the next few years with a gain in sensitivity of two orders of magnitude.

References

1. A. Benoit et al.: Phys. Lett. B **545**, 43–49 (2002)
2. A. Bottino et al.: Nuclear Physics B (Proc. Suppl.) **114**, 27–37 (2003)
3. G. Angloher et al.: Astropart. Phys. **18**, 43–55 (2002)
4. R. Bernabei et al.: Phys. Lett. B **480**, 23–31 (2000)
5. D.S. Akerib et al.: hep-ex/0306001
6. A. Morales et al.: Phys. Lett. B **532**, 8–14 (2002)
7. R. Luscher for the Boulby Dark Matter Collaboration: astro-ph/030531
8. J. Ahrens et al.: Phys. Rev. D **66**, 032006 (2002)
9. Antares Collaboration: Astropart. Phys. **19**, 253–267 (2003)
10. C. Berger et al.: N.I.M. A **262**, 463–495 (1987)
11. X.F. Navick et al.: N.I.M. A **444**, 361–363 (2000)
12. A. Benoit et al.: Phys. Lett. B **513**, 15–22 (2001)
13. C.J. Copi and L.M. Krauss: Phys. Rev. D **67**, 103507 (2003)
14. MACRO Collaboration: Astropart. Phys. **19**, 313–328 (2003)
15. Fréjus Collaboration: Astropart. Phys. **4**, 217–225 (1996)