EDELWEISS Dark Matter search using ionization-heat germanium bolometers at the Frejus Underground Laboratory

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Abstract

Recent astrophysical observations lead to the conclusion that the Universe is about critical. The matter content appears to represent approximately one third of this critical density, and is mostly composed of non baryonic Dark Matter. The leading candidates are the supersymmetric particles and most notably the neutralino, a stable particle created shorly after the Big Bang. The EDELWEISS experiment is an experiment dedicated to the direct search of these relic Weakly Interacting Massive Particles (WIMP) with low temperature Germanium bolometers detecting both the heat and ionisation signals. The recent results reported here [1] exclude previous candidate from scintillator experiment at room temperature (DAMA). Directions for future developments are also presented.

Key words: Bolometer ; Dark Matter ; Cosmology ; WIMP

1. Introduction

Cryogenic detectors appear more and more as a very promising path in the art of particle detection. Allowing in principle a very low threshold, when a measure of the deposited heat is performed, because of a T^3 decrease of the heat capacity, they have furthermore the possibility of discriminating between nuclear or electron recoil if the ionisation is also measured. Germanium double-detection bolometers [2] are used by the EDELWEISS experiment to detect relic neutralinos. Theses particles, which interact weakly with nuclei, have reachable cross sections if they have a coherent (spin independent) coupling [3] . They produce nuclear recoils in the 1 to 100 keV energy range.

Recently obtained results with 320 g Germanium detectors [1] are presented in the following.

To minimize muon induced and radioactivity backgrounds, this experiment is settled in the Frejus Underground Laboratory (Laboratoire Souterrain de Modane), where the muon flux is reduced by a factor 210^6, in a specific dilution cryostat made of very radiopure components. The cryostat is protected by low activity lead and copper shields, flushed with nitrogen to avoid radon, and finally embedded in a paraffine shield to slow down rapid neutrons, which otherwise are giving ultimately similar recoil events to WIMP's.

2. The 2002 results

After a noticeable progress in the performance of a detector with aluminium electrodes operated in the year 2000 [4] , we have redesigned the wiring of the cryostat and brought significant improvements in the thermal design of the 320 g Germanium detectors. Moreover, for one of the 3 recently operated detectors, GGA1, we have added an amorphous Germanium layer [5] under the aluminium electrodes collecting the charges. Specifications and calibrations of these 3 detectors are reported elsewhere in this conference [2] .

The results presented here are relative to data collected with the GGA1 detector during a few months run. The figure 1 shows a diagram of the ratio Q of the

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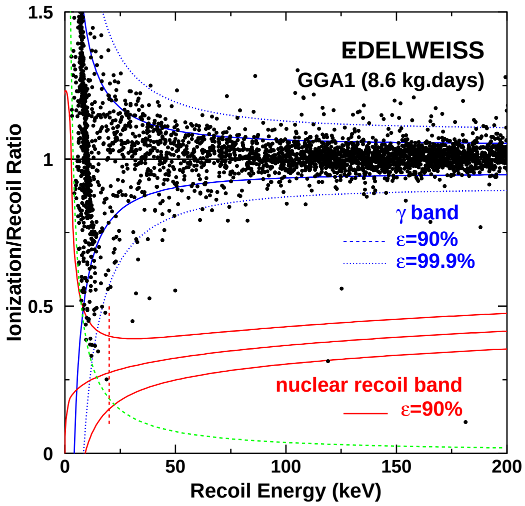

Fig. 1. Distribution of the Q factor (see text) as a function of the recoil energy from the data collected in the center fiducial volume of the 320 g EDELWEISS detector GGA1. Also plotted are the $\pm 1.65\sigma$ bands (90% efficiency) for photons and for nuclear recoils and the 99.9% efficiency region for photons. The hyperbolic dashed curve corresponds to 3.5 keV ionisation energy and the vertical dashed line to the threshold recoil energy of 20 keV used in the present analysis.

ionisation signal to the recoil energy versus the recoil energy for all events obtained in this run, corresponding to a fiducial exposure of 8.6 kg.d. Electromagnetic interactions are expected at Q=1 while nuclear interactions from WIMPs and neutrons induce values in the Q=0.3 range, depending on the recoil energy.

No event appears in the nuclear recoil band from 20 keV to 120 keV. When compared to the expected rate from WIMPs, using standard halo models for dark matter and standard nuclear physics assumptions, we extract an exclusion curve which is shown in figure 2. These results, in which no questionable subtraction of the background is done (as opposed to CDMS analysis [6]) are incompatible with the DAMA result, a scintillator room temperature experiment [7], claiming the presence of a neutralino in the 60 GeV mass region.

3. Conclusion

Searching for WIMP Dark Matter at the Frejus Underground Laboratory with a 320 g Ge double heat and ionisation detection bolometer at very low temperature, in an extremely radiopure environnement, led to the best world sensitivity for the spin independent interaction [1]. This experiment excludes at more than 99.8% the previous DAMA result obtained with a nearly three orders of magnitude more massive detector. In 2003, an array of 20 bolometers in a reverse innovative dilution cryostat with a volume of 50 l will be operated to further increase the sensitivity and possibly detect relic neutralinos. Assuming the electronic background can be kept at a distance, a one ton experiment could then be considered to reach the lower limit of neutralino cross section [8]. One should notice that in very large experiments at the futur LHC accelerator, SUSY particles will be crudely detected as a missing energy and momentum, similarly to the neutrinos in beta decay. This shows the complementarity of both searches and the power of these cryogenic detectors.

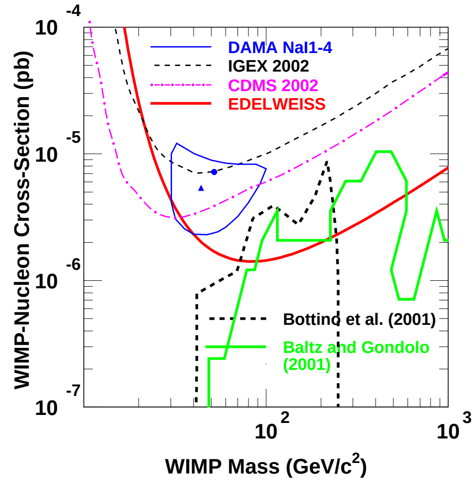

Fig. 2. Combined EDELWEISS 2000 and 2002 data spin-independent exclusion limits (dark solid curve) compared to published limits from other experiments and to the DAMA candidate region. Two examples of SUSY theoretical calculations are shown : the present data already constrain the parameter space of these models by excluding the highest cross sections (see [1] for experimental and theoretical references).

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