Present status of IGEX dark matter search at Canfranc Underground Laboratory

I.G. Irastorza\textsuperscript{a}\textsuperscript{UZ}\ Laboratory of Nuclear and High Energy Physics, University of Zaragoza, 50009 Zaragoza, Spain\textsuperscript{,}, A. Morales\textsuperscript{b}, C.E. Aalseth\textsuperscript{c} University of South Carolina, Columbia, South Carolina 29208 USA, F.T. Avignone III\textsuperscript{d}, R.L. Brodzinski\textsuperscript{e} PNL\ Pacific Northwest National Laboratory, Richland, Washington 99352 USA, S. Cebrián\textsuperscript{f}\textsuperscript{UZ}, E. García\textsuperscript{g}\textsuperscript{UZ}, I.V. Kirpichnikov\textsuperscript{h} ITEP\ Institute for Theoretical and Experimental Physics, 117 259 Moscow, Russia, A.A. Klimenko\textsuperscript{i}, H.S. Miley\textsuperscript{j} PNL, J. Morales\textsuperscript{k}\textsuperscript{UZ}, J. Puimedó\textsuperscript{o}\textsuperscript{UZ}, J.H. Reeves\textsuperscript{p} PNL, S.B. Osetrov\textsuperscript{m} INR Institute for Nuclear Research, Baksan Neutrino Observatory, 361 609 Neutrino, Russia, V.S. Pogosov\textsuperscript{n} YPI\ Yerevan Physical Institute, 375 036 Yerevan, Armenia, A.A. Smolnikov\textsuperscript{r} INR, A.G. Tamanyan\textsuperscript{s} YPI, A.A. Vasenko\textsuperscript{t} INR, S.I. Vasiliev\textsuperscript{u} INR, J.A. Villar\textsuperscript{v} UZ.

\textsuperscript{a}\textsuperscript{[}Laboratory of Nuclear and High Energy Physics, University of Zaragoza, 50009 Zaragoza, Spain\textsuperscript{]}
\textsuperscript{b}\textsuperscript{[}University of South Carolina, Columbia, South Carolina 29208 USA\textsuperscript{]}
\textsuperscript{c}\textsuperscript{[}University of South Carolina, Columbia, South Carolina 29208 USA\textsuperscript{]}
\textsuperscript{d}\textsuperscript{[}Pacifi c Northwest National Laboratory, Richland, Washington 99352 USA\textsuperscript{]}
\textsuperscript{e}\textsuperscript{[}Pacifi c Northwest National Laboratory, Richland, Washington 99352 USA\textsuperscript{]}
\textsuperscript{f}\textsuperscript{[}University of Zaragoza, 50009 Zaragoza, Spain\textsuperscript{]}
\textsuperscript{g}\textsuperscript{[}University of Zaragoza, 50009 Zaragoza, Spain\textsuperscript{]}
\textsuperscript{h}\textsuperscript{[}Institute for Theoretical and Experimental Physics, 117 259 Moscow, Russia\textsuperscript{]}
\textsuperscript{i}\textsuperscript{[}Institute for Theoretical and Experimental Physics, 117 259 Moscow, Russia\textsuperscript{]}
\textsuperscript{j}\textsuperscript{[}Pacifi c Northwest National Laboratory, Richland, Washington 99352 USA\textsuperscript{]}
\textsuperscript{k}\textsuperscript{[}University of Zaragoza, 50009 Zaragoza, Spain\textsuperscript{]}
\textsuperscript{l}\textsuperscript{[}University of Zaragoza, 50009 Zaragoza, Spain\textsuperscript{]}
\textsuperscript{m}\textsuperscript{[}Institute for Nuclear Research, Baksan Neutrino Observatory, 361 609 Neutrino, Russia\textsuperscript{]}
\textsuperscript{n}\textsuperscript{[}Yerevan Physical Institute, 375 036 Yerevan, Armenia\textsuperscript{]}
\textsuperscript{o}\textsuperscript{[}University of Zaragoza, 50009 Zaragoza, Spain\textsuperscript{]}
\textsuperscript{p}\textsuperscript{[}Pacifi c Northwest National Laboratory, Richland, Washington 99352 USA\textsuperscript{]}
\textsuperscript{q}\textsuperscript{[}University of Zaragoza, 50009 Zaragoza, Spain\textsuperscript{]}
\textsuperscript{r}\textsuperscript{[}Institute for Theoretical and Experimental Physics, 117 259 Moscow, Russia\textsuperscript{]}
\textsuperscript{s}\textsuperscript{[}Yerevan Physical Institute, 375 036 Yerevan, Armenia\textsuperscript{]}
\textsuperscript{t}\textsuperscript{[}Institute for Theoretical and Experimental Physics, 117 259 Moscow, Russia\textsuperscript{]}
\textsuperscript{u}\textsuperscript{[}Institute for Theoretical and Experimental Physics, 117 259 Moscow, Russia\textsuperscript{]}
\textsuperscript{v}\textsuperscript{[}University of Zaragoza, 50009 Zaragoza, Spain\textsuperscript{]}

One IGEX \(^{76}\text{Ge}\) double-beta decay detector is currently operating in the Canfranc Underground Laboratory in a search for dark matter WIMPs, through the Ge nuclear recoil produced by the WIMP elastic scattering. A new exclusion plot, \(\sigma(m)\), has been derived for WIMP-nucleon spin-independent interactions. To obtain this result, 40 days of data from the IGEX detector (energy threshold \(E_{\text{thr}} \sim 4\) keV), recently collected, have been analyzed. These data improve the exclusion limits derived from all the other ionization germanium detectors in the mass region from 20 GeV to 200 GeV, where a WIMP supposedly responsible for the annual modulation effect reported by the DAMA experiment would be located. The new IGEX exclusion contour enters, by the first time, the DAMA region by using only raw data, with no background discrimination, and excludes its upper left part. It is also shown that with a moderate improvement of the detector performances, the DAMA region could be fully explored.

1. Introduction

Recent cosmological observations and robust theoretical arguments require an important Dark Matter component (\(\Omega_{DM} \sim 25 - 30\%\)) in our universe, which is supposed to be made mostly of non-baryonic particles. Weakly Interacting Massive (and neutral) Particles (WIMPs), which are favourite candidates to such non-baryonic component, could fill the galactic halos accounting for the flat rotation curves which are measured for many galaxies. They could be detected by measuring the nuclear recoil produced by their elastic scattering off target nuclei in a suitable detector [1]. In this talk new WIMP constraints derived from a germanium detector of the IGEX collaboration are presented. They improve previous limits obtained with Ge ionization detectors, and enter by the first time the so-called DAMA region (corresponding to a WIMP supposedly respon-
sible for the annual modulation effect found in the DAMA experiment [2]) without using mechanisms of background rejection, but relying only on the ultra-low background achieved.

2. Experiment

The IGEX experiment [3,4], optimized for detecting $^{76}$Ge double-beta decay, has been described in detail elsewhere. One of the IGEX detectors of 2.2 kg (active mass $\sim 2.0$ kg), enriched up to 86% in $^{76}$Ge, is being used to look for WIMPs interacting coherently with the germanium nuclei. The Ge detector and its cryostat were fabricated following state-of-the-art ultralow background techniques and using only selected radiopure material components (see Ref [3,5]).

The detector shielding has been recently modified with respect to that of the previous set-up of Ref. [5]. The improvements concern basically the neutron moderator. We have doubled its thickness (40 cms of polyethylene and borated water tanks) and now it much better covers the whole set-up, due to the removal of the other detectors (RG-I, RG-III and COSME), which dewars did not allow us to perfectly close the polyethylene wall. These changes were motivated by a previous study of the possible sources of background in IGEX based on several simulations, which pointed out that the neutrons from the surrounding rock could contribute considerably to the low energy background. For more details on the IGEX shielding we refer to [5] and [12].

In addition to the data acquisition system used in previous runs (described in [5]), a specific pulse shape analysis has been implemented for the data set presented in this talk. The pulse shapes of each event before and after amplification are recorded by two 800 MHz LeCroy 9362 digital scopes. These are analyzed one by one by means of a method based on wavelet techniques which allows us to assess the probability of this pulse to have been produced by a random fluctuation of the baseline. This probability is used as a criterion to reject events coming from electronic noise or microphonics. According to the calibration of the method, it works very efficiently for events above 4 keV.

3. Results and prospects

The results presented in this talk are from a recent run of an exposure of Mt=80 kg days with the modified set-up previously mentioned. The spectrum obtained is shown in Figure 1 compared with the previous IGEX published spectrum of Ref. [5].

The energy threshold of the detector is 4 keV and the FWHM energy resolution at the 75 keV Pb X-ray line was of 800 eV. The background rate recorded was $\sim 0.21$, $\sim 0.10$ and $\sim 0.04$ c/keV/kg/day between 4–10 keV, 10–20 keV, and 25–40 keV respectively. As it can be seen, the background below 10 keV has been substantially reduced (about a factor 50%) with respect to that obtained in the previous set-up [5], essentially due to the improved shielding (both in lead and in polyethylene-water). This suggests that the neutrons could be an important component of the low energy background in IGEX.

The exclusion plot is derived from the recorded spectrum following the same set of hypothesis and parameters used in previous papers (see [5]) and is shown in Fig. 2 (thick solid line). It improves the IGEX-DM previous result (thick dashed line) as well as that of the other previous germanium ionization experiments (including the last result of Heidelberg-Moscow experiment [6] –thick dotted line–) for a mass range from 20 GeV to 200 GeV, which encompass that of the DAMA
mass region. In particular, this new IGEX result excludes WIMP-nucleon cross-sections above $7 \times 10^{-9}$ nb for masses of $\sim 50$ GeV and enters the so-called DAMA region [2] where the DAMA experiment assigns a WIMP candidate to their found annual modulation signal. IGEX excludes the upper left part of this region. That is the first time that a direct search experiment without background discrimination, but with very low (raw) background, enters such region. Also shown for comparison are the contour lines of the other experiments which have entered that region.

Data collection is currently in progress and some strategies are being considered to further reduce the low energy background. If this reduction is achieved, very interesting perspectives can be set for IGEX. In Fig. 3 we plot the exclusions obtained with a flat background of 0.1 c/kg/keV/day (dot-dashed line) and of 0.04 c/kg/keV/day (solid line) down to the current 4 keV threshold for an exposure of 1 kg year. In particular, the complete DAMA region could be tested with a moderate improvement of the IGEX performances. The dashed line in Fig. 3 corresponds to a flat background of 0.002 c/kg/keV/day down to a threshold of 4 keV and 24 kg y of exposure, which are the parameters expected for GEDEON (GERmanium DEtectors in ONe cryostat), a new experimental project on WIMP detection using larger masses of natural germanium planned as an extension of the IGEX dark matter search (see ref. [12]). GEDEON would be massive enough [11] to search also for the WIMP annual modulation effect and explore positively an important part of the WIMP parameter space including the DAMA region.

REFERENCES


Figure 2. IGEX-DM exclusion plot for spin-independent interaction obtained in this work (thick solid line) compared with the previous exclusion obtained by IGEX-DM [5] (dashed thick line) and the last result obtained by the Heidelberg-Moscow germanium experiment [6] (dotted line) recalculated from the original spectrum with the same set of hypothesis and parameters. The closed line corresponds to the ($3\sigma$) annual modulation effect reported by the DAMA collaboration (including NaI-1,2,3,4 runnings) [2]. The thin solid line is the exclusion line obtained by DAMA NaI-0 [9] by using Pulse Shape Discrimination. The two other experiments which have entered the DAMA region are also shown: EDELWEISS [8] (thin dashed line) and the CDMS (For which two contour lines have been depicted according to a recent recommendation [10], the exclusion plot published in Ref. [7] –thin dotted line– and the CDMS expected sensitivity contour [7] –thin dot-dashed line–).

Figure 3. IGEX-DM projections are shown for a flat background rate of 0.1 c/keV/kg/day (dot-dashed line) and 0.04 c/keV/kg/day (solid line) down to the threshold at 4 keV, for 1 kg year of exposure. The exclusion contour expected for GEDEON is also shown (dashed line) as explained in the text.
10. B. Sadoulet, private communication to A. Morales and B. Sadoulet, these proceedings.