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Results with the DAMA/LXe experiment at LNGS

R. Bernabei[a], P. Belli[a], F. Cappella[a], R. Cerulli[a], C.J. Dai[b], A. Incicchitti[c], F. Montecchia[a], D. Prosperi[c] *

[a]Dip.to di Fisica, Università di Roma "Tor Vergata" and INFN, sez. Roma2, I-00133 Rome, Italy

[b]IHEP, Chinese Academy, P.O. Box 918/3, Beijing 100039, China

[c]Dip.to di Fisica, Università di Roma "La Sapienza" and INFN, sez. Roma, I-00185 Rome, Italy

DAMA experiment is an observatory for rare events mainly devoted to WIMP search at the Gran Sasso National Laboratory of the I.N.F.N.. In this paper, the most recent results obtained with the $\simeq$ 6.5 kg liquid Xenon set-up are briefly summarized.

We pointed out the interest in using liquid Xenon as target-detector for particle dark matter search deep underground since ref. [1]. Several prototypes were built and related results published [2]. The final choice was to realize a pure liquid Xe scintillator directly collecting the emitted UV light and filled with Kr-free Xenon gas isotopically enriched. The detailed description of this set-up and of its performances have been given in ref. [3]. Kr-free Xenon enriched in ^{129}Xe at 99.5% has been used since time, while more recently the set-up has been modified in order to run alternatively either with this gas or with Kr-free Xenon enriched in ^{136}Xe at 68.8%.

After preliminary measurements both on elastic and inelastic WIMP-^{129}Xe scattering [4,5], the recoil/electron light ratio and the pulse shape discrimination capability in a similar pure LXe scintillator have been measured both with Am-B neutron source and with 14 MeV neutron generator [6]. After some upgrading of the set-up, new results on the WIMP search have been obtained [6, 7]. In particular, in ref. [6] the pulse shape discrimination in pure LXe scintillators has been exploited (see Fig 1). Moreover, in 2000/2001 further measurements on the recoil/electron light ratio with 2.5 MeV neutron generator have been carried out at ENEA-Frascati; see ref. [8] for details and comparisons. Fig 2 summarizes the measured values.

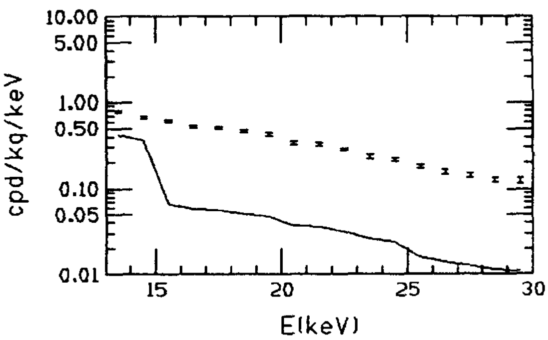

Figure 1. Low energy distribution (statistics of 1763.2 kg·day – DAMA/Xe-2 period) when the vessel is filled with ^{129}Xe; the continuous line represents the upper limits at 90% C.L. obtained for the recoil fractions [6].

The inelastic excitation of ^{129}Xe by Dark Matter particles with spin-dependent coupling has

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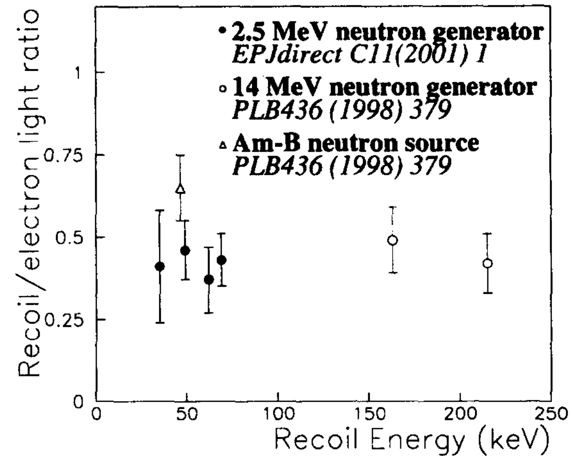

Figure 2. Measured behaviour of the recoil/electron light ratio with recoil energy. Note that the energy of the data point of AmB neutron source is an average which refers also to much lower energies than those explored with the 2.5 MeV neutrons.

also been preliminarily searched for in ref. [5] and, more recently, in ref. [7] (see Fig 3). We remind that large mass would be necessary to approach a suitable sensitivity when investigating such a WIMP-nucleus inelastic scattering.

Other rare processes have been investigated by filling the detector with the Kr-free Xenon gas enriched in ^{129}Xe at 99.5%. In particular, as regards the electron stability, limits on the lifetime of the electron decay in both the disappearance and the $\nu_e + \gamma$ channels were set in ref. [9]. The latter has been more recently improved to: $2.0(3.4) \cdot 10^{26}$ y at 90% (68%) C.L. [10]. Furthermore, new lifetime limits on the charge non-conserving electron capture with excitation of ^{129}Xe nuclear levels have been established to be in the range $(1-4) \cdot 10^{24}$ y at 90% C.L. for the different excited levels of ^{129}Xe [11]. The most stringent restrictions on the relative strengths of charge non-conserving processes have been derived: $\epsilon_W^2 < 2.2 \times 10^{-26}$ and $\epsilon_\gamma^2 < 1.3 \times 10^{-42}$ at 90% C.L.

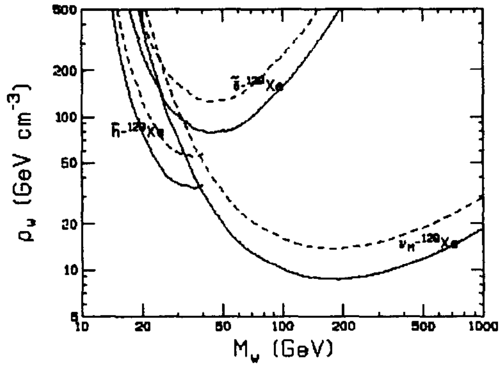

Figure 3. Results on the WIMP-^{129}Xe inelastic scattering: limits on the relic halo density for photino, higgsino and and ν_M as a function of the WIMP mass (full lines). The broken lines are our previous limits of ref. [5]. For the considered model framework see ref. [7].

Moreover, we have searched for the nucleon and di-nucleon decay into invisible channels [12] by a new approach. In fact, the radioactive daughter nuclei, created after the nucleon or di-nucleon disappearance in the parent nuclei, have been investigated. This approach has the advantage of a branching ratio close to 1 and – if the parent and daughter nuclei are located in the detector itself – also of an efficiency close to 1. The obtained limits at 90% C.L. are: $\tau(p \rightarrow$ invisible channel) $> 1.9 \cdot 10^{24}$ y; $\tau(pp \rightarrow$ invisible channel) $> 5.5 \cdot 10^{23}$ y and $\tau(nn \rightarrow$ invisible channel) $> 1.2 \cdot 10^{25}$ y. These limits are similar or better than those previously available; the limits for the di-nucleon decay in $\nu_\tau \bar{\nu}_\tau$ have been set for the first time; moreover, these limits are valid for every possible disappearance channel [12].

Finally as mentioned above, more recently the set-up has been modified to allow the use of Kr-free Xenon enriched in ^{136}Xe at 68.8%. Preliminary measurements have been carried out dur-

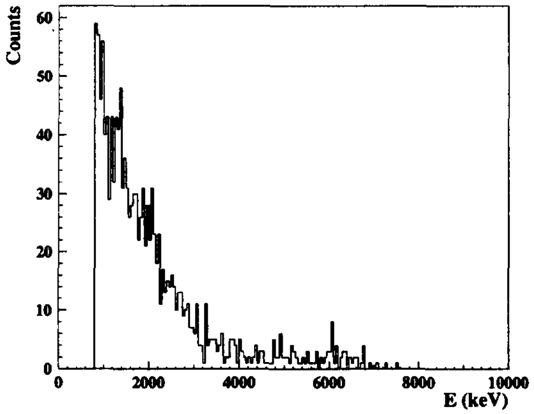

Figure 4. High energy experimental energy distribution (6843.8 hours) when the vessel is filled with ^{136}Xe. It has been used to derive new limits on $\beta\beta$ decay processes in ^{136}Xe. The energy bin is 50 keV [13].

ing 6843.8 hours (see Fig 4) [13]. In this way, new experimental limits have been obtained for the considered $\beta\beta$ decay processes in ^{136}Xe, improving the limits previously available by factors ranging between 1.5 and 65. In particular, for the 3 possible channels without neutrinos the following half life limits (90% C.L.) have been achieved: $7.0 \cdot 10^{23}$ y for the channel $\beta\beta$ $0\nu(0^+ \rightarrow 0^+)$; $4.2 \cdot 10^{23}$ y for the channel $\beta\beta$ $0\nu(0^+ \rightarrow 2^+)$; $8.9 \cdot 10^{22}$ y for the channel $\beta\beta$ $0\nu M(0^+ \rightarrow 0^+)$. For comparison, we note that the obtained experimental limits on the half life of the process $\beta\beta$ $0\nu(0^+ \rightarrow 0^+)$ is lower only than the one obtained for the case of ^{76}Ge, while the limits (90% C.L.) on the channels $\beta\beta$ $2\nu(0^+ \rightarrow 0^+)$: $> 1.1 \cdot 10^{22}$ y, and $\beta\beta$ $0\nu M(0^+ \rightarrow 0^+)$: $> 8.9 \cdot 10^{22}$ y, are at present the most stringent ones not only for the ^{136}Xe isotopes, but also for every kind of nucleus investigated so far either by active or by passive source method. Furthermore, upper bounds on the effective neutrino mass have been set considering various theoretical models for the evaluation of the elements of the nuclear matrix; they vary between 1.5 eV and 2.2 eV (90% C.L.). Finally, in the framework of the same models we have also obtained upper limits on the effective coupling constant Majoron - neutrino; they range in the interval: $4.8 \cdot 10^{-5}$ and $7.1 \cdot 10^{-5}$ (90% C.L.).

In conclusion, competitive results have been achieved by the DAMA LXe set-up by using Kr-free isotopically enriched Xenon.

Further upgradings to improve the detector performance are under consideration, while the data taking is continuing alternatively with both enrichments.

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