-A

LNGS - 94/108
October 1994

PARTICLE DARK MATTER SEARCH WITH LOW ACTIVITY SCINTILLATORS: STATUS REPORT

presented by A. Incicchitti
for the BPRS collaboration

C. BACCI[a], P. BELLI[b], R. BERNABEI[b], C.J. DAI[c], W. DI NICOLANTONIO[d], L.K. DING[c], E. GAILLARD-LECANU[e], G. GERBIER[e], Y. GIRAUD-HERAUD[f], H.H. KUANG[c], A. INCICCHITTI[g], J. MALLET[e], L. MOSCA[e], D. PROSPERI[g], C. TAO[f]
[a] Dip. di Fisica, Universitá di Roma III and INFN, sez. Roma, I-00165 Rome, Italy
[b] Dip. di Fisica, Universitá di Roma "Tor Vergata" and INFN, sez. Roma II, I-00173 Rome, Italy
[c] IHEP, Chinese Academy, P.O. Box 918/3, Beijing 100039, China
[d] Laboratori Nazionali del Gran Sasso (LNGS), S.S. 17/bis km 18+910, I-67010 l' Aquila, Italy
[e] DSM/DAPNIA/SPP, C.E. Saclay, F-91191 Gif-sur-Yvette, France
[f] Laboratoire de Physique Corpusculaire, College de France/IN2P3 (CNRS), 11, place M. Berthelot, F- 75231 Paris, France
[g] Dip. di Fisica, Universitá di Roma "La Sapienza" and INFN, sez. Roma, I-00165 Rome, Italy
and
B. CHAMBON, V. CHAZAL, M. DE JESUS, D. DRAIN, Y. MESSOUS, C. PASTOR
IPN LYON, IN2P3 (CNRS), 43 Bd. du 11 November 1918, F-69622 Villeurbanne CEDEX, France

*talk given at Vulcano Workshop "Frontier Object in Astrophysics and Particle Physics", May 23-28, 1994

Abstract

An update of the direct Dark Matter search with low activity scintillators - performed by the BPRS collaboration - is presented.

1.Introduction

Many experimental efforts are in progress to perform particle Dark Matter direct search deep underground; the technique is mainly based on the use of materials acting both as target and detector like ionization detectors (Ge, Si), scintillators (NaI(Tl), CaF_2(Eu), liquid Xenon) and bolometers (sapphire, Ge) (Smith and Lewin, 1990; Bernabei and Tao, 1994; Bernabei, 1994).

2.Search with NaI(Tl)

In 1992 our first result (C. Bacci et al., 1992; Bottino et al., 1992) demonstrated the feasibility of a Dark Matter direct detection search with scintillators: the experimental rate was about 7 cpd/kg/keV at 4 keV. A similar sensitivity has been reached in 1993 at Canfranc and Kamioka laboratories (Sarsa et al., 1994; Fushimi et al., 1993) and more recently at Boulby (Sumner et al., 1994).

In order to further reduce the low energy counting rate and enter the neutralino, χ, region we performed a careful analysis of all the crystal components with NaI(Tl) and Ge detectors deep underground, atomic absorption and mass spectrometers. We also studied different growing methods. Many detectors have been already realized and tested (see table 1).

Detector	^{39}K	*U/Th*	*weight*
Bicron (86)	1 ppm	0.07 ppb	10.7 kg
Harshaw (91)	less 0.1 ppm	$\simeq$ 0.1 ppb	0.76 kg
Q&S (93)	less 50 ppb	$\simeq$ 2 ppt	0.37/4/7 kg

Table 1: *K and U/Th contamination in various NaI(Tl)*

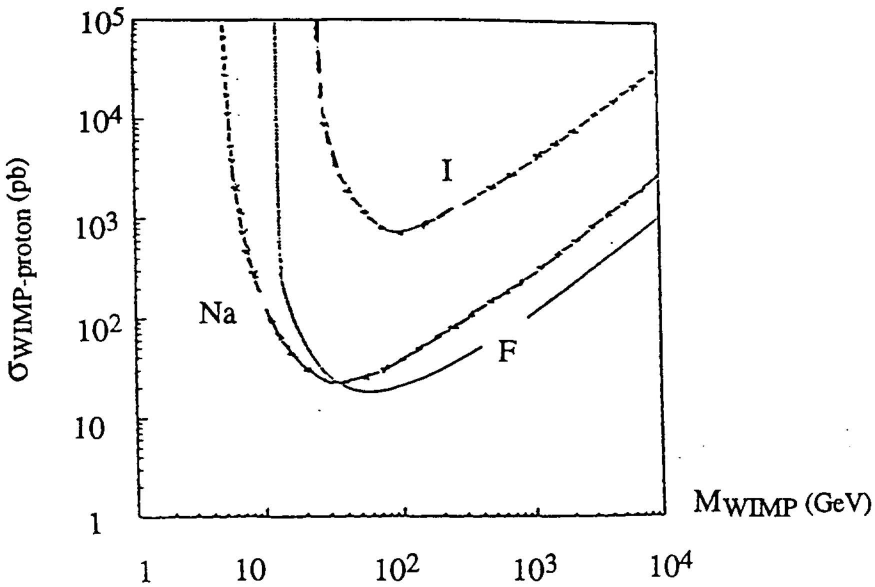

Figure 2: *Exclusion plots for 1994 data with NaI(Tl) and CaF2(Eu) crystals.*

Using a 7 kg NaI(Tl) detector with about 2 ppt U/Th and less than 50 ppb of ^{39}K just stored in the underground Gran Sasso Laboratory, seen by two low activity EMI photomultipliers, a counting rate of $\simeq$ 1 cpd/Kg/keV at $\simeq$ 4 keV has been reached. In fig. 2) the corresponding exclusion plot for axially coupled WIMPs is shown: $\simeq$ 1 order of magnitude better than in (Bacci et al., 1992) [3].

[3]For sake of completness we recall that a WIMP-nucleus inelastic scattering search has been per-

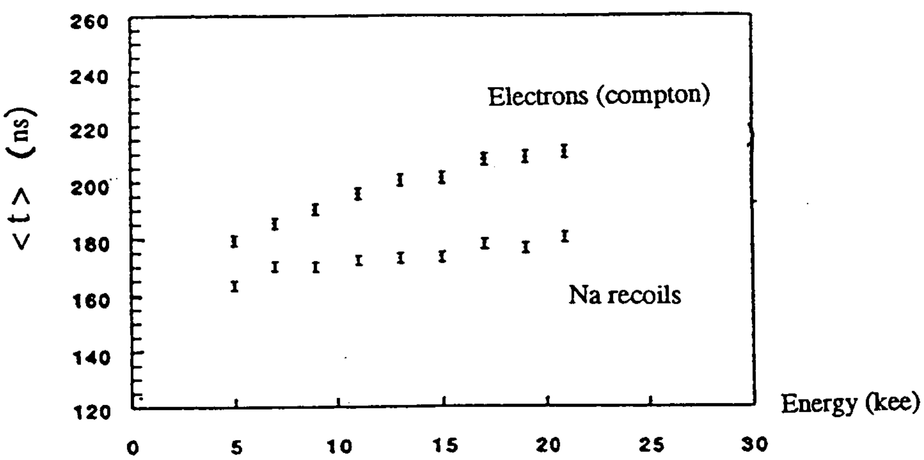

Figure 3: *Averaged mean photoelectrons arrival time for Compton electrons and Na recoil pulses as a function of energy.*

To further decrease the counting rates we follow two strategies: a) we improve the material selection and check the effect of multiple crystallizations; b) we quantitatively develop a detailed pulse shape analysis between nuclear recoils and electromagnetic background. For the last purpose careful measurements have been performed at Bruyères Le Chatel studying also the effect of the temperature variations. A preliminary analysys has been done on low statistics samples. To illustrate the difference in the shapes of the pulses from Na recoils and electrons, the mean photoelectron arrival time calculated on the first 1200 ns has been calculated as a function of energy for the two populations (fig. 3). The relative difference ranges from about 8% at 5 keV to about 13% at 20 keV. The rejection power which can be obtained from this difference depends on many factors and in particular on systematic effects from electronics and temperature. This study is under way with high statistics samples.

A new analysis considering PSD information on data collected in LNGS with 5 detectors for 40 kg of total mass is in progress. Optimizing the light collection an energy threshold of 2 keV has been reached.

We recall here that tests with bare crystals have been performed to properly evaluate the detection efficiency near the thresholds; it was $\simeq$ 100 % with a 2 keV threshold. A low Z window is now present in our detector to allow us to calibrate sistematically down to the ^{55}Fe X-rays (6 keV) as part of our routine calibration procedures [4].

3.Search with $CaF_2(Eu)$

The first results on a direct search for axially coupled WIMP on ^{19}F has been published (Bacci et al., 1994) using a 3" diameter 1" long $CaF_2(Eu)$ detector. Although the counting rate is for the moment relatively high (about 15 cpd/Kg/keV at about 4 keV), the very favourable spin factor for fluorine allows to obtain an already interesting

formed looking for the 57.6 keV disexcitation line of ^{127}I (Fushimi et al., 1994); however, although the authors quote a stringent exclusion plot, a critical MonteCarlo modelling and subtraction of background are performed to try extracting an upper limit on the signal from a large experimental differential rate, that strongly reduces the reliability of the result.

[4]The possibility to use a large set of γ sources even at very low energy is extremely important considering the behaviour of the NaI(Tl) light yield as a function of energy.

exclusion plot (fig. 2). A new R & D is in progress to develop higher purity detectors.

4.SIMP search by delayed coincidences

A search for very massive strongly interacting neutral particles, SIMPs (like stable H particles, bound states of ordinary quarks and gluons with heavy stable quarks, scalar quarks, gluinos or other exotic possibilities) with $\beta \simeq 10^{-3}$ has been performed by the study of delayed coincidences between two planes of low activity NaI(Tl) (Goodman and Witten, 1985; Starkman et al., 1990).

A first result has been published in (Bacci et al., 1994).

Three prototype set-ups - two running in Gran Sasso and one in Modane - allow us to obtain the new exclusion plots shown in fig. 4.

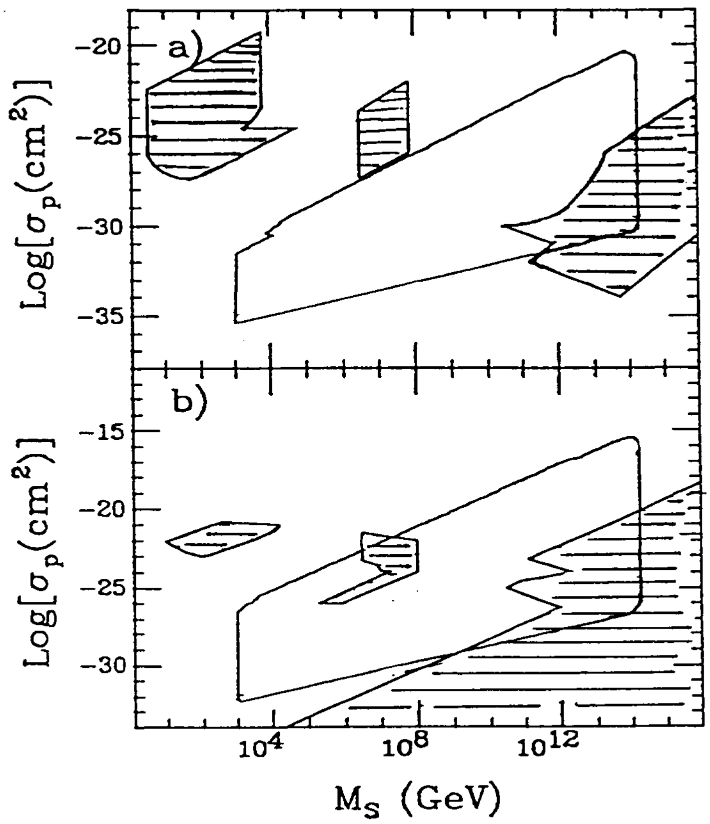

Figure 4: *New exclusion plots for neutral SIMPs from the data of three prototype set-ups installed in LNGS and LSM: coherent (a) and spin dependent (b) coupling.*

The measured delayed coincidences (6 in total in the mainly single scattering region:10-60 keV electron equivalent) are not inconsistent with the expected random coincidences; zero event has been observed in the multiple scattering region. Presently the final set-up - with a much larger acceptance and well reduced random coincidence rate - is running at Gran Sasso.

5.Conclusion

It has been demonstrated that the scintillators have performances well suitable for particle dark matter direct search deep underground such an energy threshold of a few keV, counting rate -without any subtraction- of the order of 1 cpd/kg/keV and -in case of NaI(Tl)- pulse shape discrimination possible.

We finally recall here that to make reliable comparisons between results obtained by different experiments a careful comparison of the astrophysical, particle and nuclear physics assumptions has to be done [5]; background modelling and subtraction, microphonic noise rejection, clear quotation and use of detection efficiencies etc. play a relevant role on reliability of the results.

6.Acknowledgements

It is a pleasure to thank Dr. C. Arpesella and Profs. S. d'Angelo, and G. Heusser for many useful discussions on related topics, Mr. A. Bussolotti and G. Ranelli for technical help and the LNGS and LSM staff for support.

References

Bacci, C. et al.: 1994, LNGS-94/94 to appear in the Proceedings of the Rencontres de Moriond.
Bacci, C. et al.: 1994, Astrop. Phys. **2**, p. 117.
Bacci, C. et al.: 1992, Phys. Lett. **B293**, p. 460.
Bacci, C. et al.: 1994, Astrop. Phys. **2**, p. 13.
Bernabei, R., Tao, C. ed.: 1994, "The Dark side of the Universe: experimental efforts and theoretical framework", World Sc. Pub.
Bernabei, R.:1994, "Particle dark matter direct search in underground laboratories", ROM2F/94/33 to appear in the Proceedings of the XXII Int. Winter Meeting on "Fundamental Physics, the Standard Model and Beyond", Jaca 1994 and references quoted therein.
Bottino, A. et al.: 1992, Phys. Lett. **B295**, p. 330.
Ellis, J., Flores, R.A.: 1991, Phys. Lett. **B263**, p. 259.
Fushimi, K. et al.: 1993, Phys. Rev. **C47**, p. R425.
Fushimi, K. et al.: 1994, Nucl. Phys. **B35**, p. 400.
Gerbier, G. et al.: 1991, Proceedings of the Rencontres de Moriond, Frontiers ed.
Goodman, M. W., Witten E.: 1985, Phys. Rev. **D31**, p. 3059.
Sarsa, M.L. et al.: 1994, Nucl. Phys. **B35**, p. 154.
Smith, P. F., Lewin J. D.: 1990, Phys. Rep. **187**, p. 203.
Starkman, G.D. et al.: 1990, Phys. Rev. **D41**, p. 3594.
Sumner, T.J. et al.: 1994, to appear in the Proceedings of the Rencontres de Moriond.

[5] f.i. nuclear form factor plays a relevant role in the evaluation of the exclusion plot for nuclei with $A \geq 40$ as well as energy threshold.