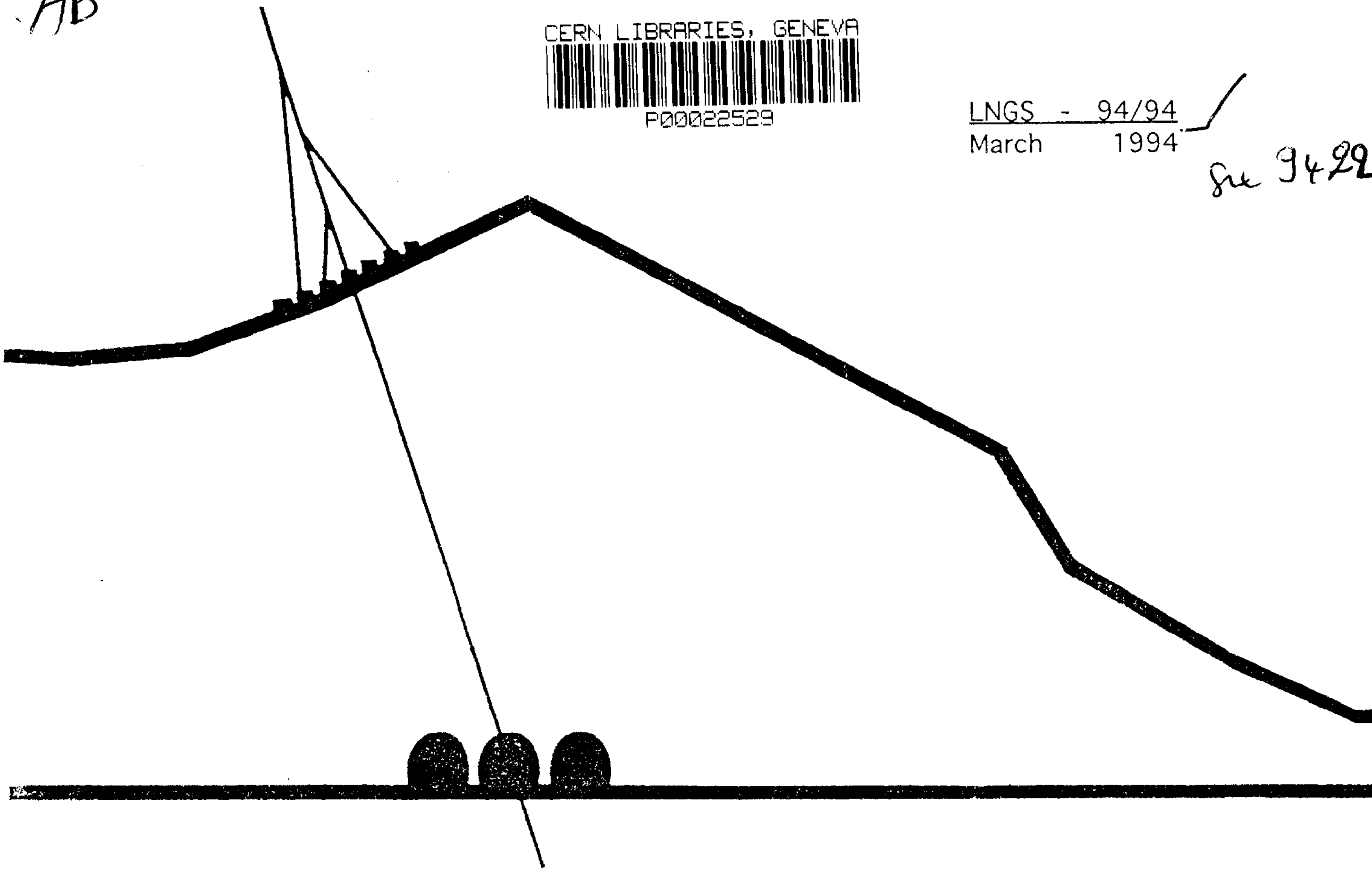
LNGS - 94/94
March 1994



NEW LIMITS ON AXIAL COUPLED WIMPs WITH SCINTILLATORS

presented by Pierluigi Belli
for the BPRS collaboration

(to appear on the Proceed. of Moriond Workshop 94)

INFN - Laboratori Nazionali del Gran Sasso

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Abstract

New results on dark matter direct search with scintillators are presented and compared with previous measurements.

Several materials have been proposed and used to direct search particle dark matter candidates [1 to 7]. Our collaboration pointed out its attention to scintillators as target-detectors and, in particular, to NaI(Tl) and CaF_2(Eu). The NaI(Tl) has an high light output and it is well suitable to build large apparata looking for the annual modulation of the rate for extemely low rate candidates as the neutralino. The CaF_2(Eu) is interesting because of the large cross section on ^{19}F of axial coupled WIMPs [8].

The ``quenching factor'' of a nucleus recoil (its scintillation efficiency compared to that of an electron with the same kinetic energy) has been measured by our collaboration at Bruyeres Le Chatel with a neutron beam with NaI(Tl) and CaF_2(Eu), obtaining: Q_{Na}=0.25 [9], Q_I=0.08, Q_F=0.07 [10] and Q_{Ca}=0.05 [10] (see fig. 1). The feasibility of a pulse shape statistical rejection - at low energy - of the γ/e background in NaI(Tl) has been also demonstrated [9,14].

A large number of measurements has been performed in Gran Sasso and Frejus

Laboratories and Mentogou mine with various detectors of different size and composition, made by European, American and Chinese companies.

A first experiment was done with a 760g NaI(Tl) crystal [5]; in fig. 2 the obtained exclusion plots on I and Na are shown. This result was the first demonstration of the feasibility of a dark matter experiment with scintillators; successively other groups reached similar sensitivities with NaI(Tl) of various size and origin[11,12,13].

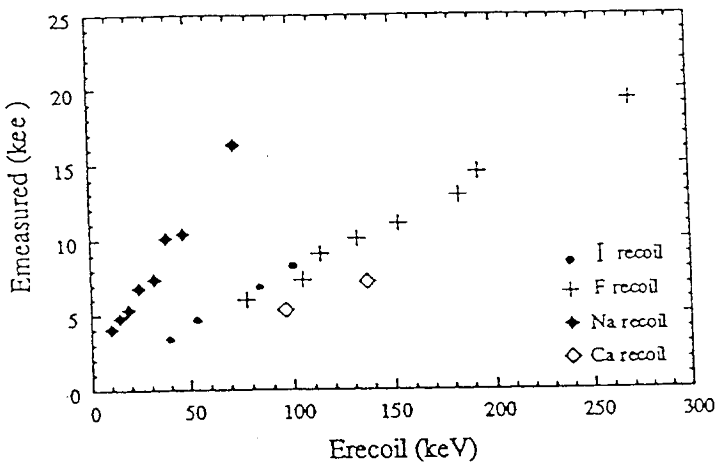

Fig. 1 : Response of NaI(Tl) to Na[9] and I recoils and of CaF_2(Eu) to F[10] and Ca[10] recoils.

We evaluated the expected rates for the neutralino as a dark matter particle and reported them in ref. [6]. These calculation showed that we need to improve by at least one order of magnitude the detector quality to reach the most optimistic neutralino allowed region.

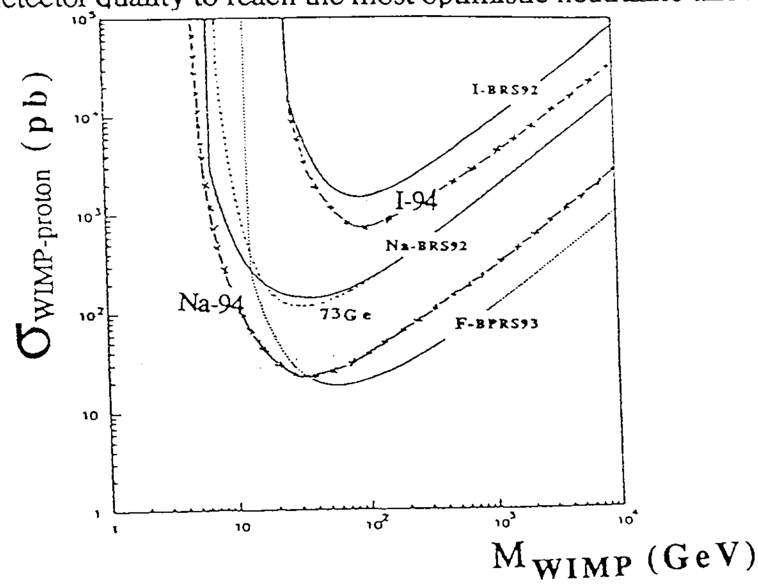

Fig. 2: Exclusion plots for axially coupled WIMPs derived from our measurements: Na and I nuclei 1992 [5]; new results for Na and I nuclei 1994; first results on F 1993. The exclusion plot on ^{73}Ge - derived from the data of ref. [4] - is shown for comparison.

To achieve this result, we carefully measured and selected all the detector components which were used in new detectors. Thorn-EMI provided us an improved low radioactive background photomultiplier which contributes to the experimental rate a factor 15 to 50 less than previous ones. Detectors with strongly reduced natural impurities have been obtained: $^{238}U/^{232}Th \sim 2$ ppt and $^{39}K<0.05$ ppm ($2\,\sigma$ CL) [14].

Recently+) a new set of four detectors, 7 Kg each, have been measured; three of them were used as anticoincidence for the inner one (reduction rate of about 15 %). Each detector was seen by one PMT on each end through a low activity light guide; a low Z window allowed us a calibration with ^{55}Fe source (5.9 keV X-rays), see fig.3.

A preliminary result - obtained just after underground storage of the detector and with a not fully efficient radon removal - is show in fig. 4; the corresponding exclusion plot is reported also in fig.1. The counting rate is expected to still more decrise by improving the radon removal system and the nearest materials quality and waiting for the decreasing of the short life contaminants. However, we have already reached with these very preliminary measurements an improvement in the exclusion plot of a factor ~ 5.

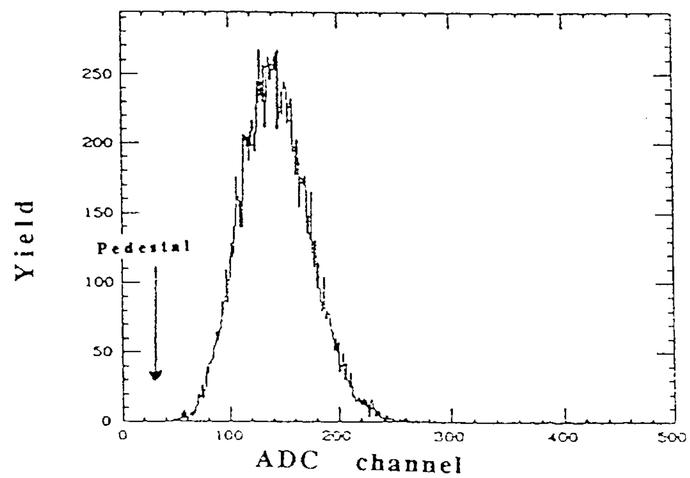

Fig. 3: The ^{55}Fe source as seen - through a low Z window - by the 7 Kg NaI(Tl) detector having a straight light guide and a low activity photomultiplier on each side.

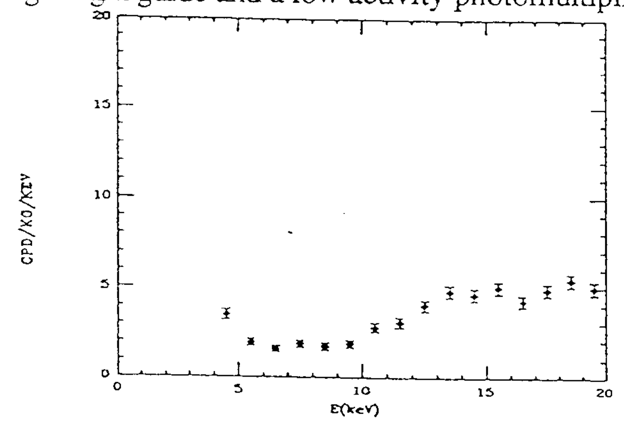

Fig. 4: Preliminary experimental rate of the 7 Kg NaI(Tl) detector at beginning of underground storage. The radon removal and the environmental background are not yet optimized.

+) In fact, these results from the 7 Kg detectors have been presented about one month later at Berkeley workshop, for which no proceedings were planned.

A similar sensitivity on axial coupled WIMPs have been also obtained with a 0.37 kg $CaF_2(Eu)$ [10] crystal directly coupled on one end to a very low activity EMI photomultiplier. At the other side to a low activity NaI(Tl) was installed as anti-Compton detector (rate reduction ~ 30% at low energy). The detector has been calibrated with the ^{55}Fe source. From the high energy spectrum we derive a contamination of 0.05 ppb for ^{238}U and 0.16 ppb for ^{232}Th.

The quoted exclusion plots have been evaluated under the following assumptions: the WIMPS are distributed in a spherical halo with a local density in the solar neighbourhood of 0.3 GeV/cm^3; their velocities follow a Maxwellian distribution in the Galactic frame (truncated at a value V_{esc}) with an average velocity V_{rms} equal to sqrt(3/2) V_c, where V_c ~ 220 km/s is the circular solar velocity. Transformation to the laboratory frame is computed with an Earth velocity equal to about 235 km/s. In the calculation of the expected rates, we have included the experimental energy resolution, the spin factors as calculated in the odd group model by Ellis and Flores [8] and a spin form factor with a Bessel function shape as for the mass form factor of Engel (1991) in reference [15]. Ellis and Flores (1991) suggested a correction for the spin radius with respect to the charge radius which they tabulated in ref [8] for different nuclei. This is taken into account. For ^{73}Ge, the data are from ref. [4]; we should point out that an additional source of difficulty in comparing these data with other nuclei, arises from the fact that its unpaired nucleon is a neutron, while for the other 3 nuclei, the unpaired nucleon is a proton.

We would like to stress the important role played by the form factor correction in the case of heavy nuclei ($A \geq 40$).

In conclusion, we presented here new results on CDM search with scintillators. We plan to improve the anti-Compton rejection and to further work on purification possibilities of the detector materials.

Acknowledgements

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