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Cryogenic thermal detectors as a powerful way to analyse internal activities

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Abstract

The Milano group is using an array of four crystals of TeO_2, 334 g each, to search for neutrinoless double beta decay of ^{130}Te [A. Alessandrello et al., Phys. Lett. B 335 (1994) 519; Proc. 4th Int. Workshop on Theoretical and Phenomenological Aspects of Underground Physics – TAUP 95, to be published in Nucl. Phys. B (Proc. Suppl)]. The detectors are operating in a dilution refrigerator installed in the Underground National Laboratory of Gran Sasso specially built with low activity materials. Due to the low external background and the good energy resolution it is possible to obtain precise measurements of some internal contaminations of the detector itself. An analysis of a contamination of ^{210}Po and of the decay of ^{123}Te is presented.

1. Contamination of ^{210}Po

Polonium is a common source of contamination of the tellurium compounds due to their chemical affinity. In our detectors the internal contamination of ^{210}Po gives a peak at 5407 keV that is the total energy of the transition $^{210}Po \rightarrow {}^{206}Pb$, i.e. the energy of the α particle plus the energy of the recoiling nucleus (one important property of the bolometric detectors is to be sensitive to non-ionising events).

The rate of this peak, is found to decrease with a lifetime of 138 ± 1 days in excellent agreement with what is expected for ^{210}Po. A much weaker satellite peak at an energy of about 5300 keV is present (Fig. 1) and is attributed to the α-energy alone and indicates a ^{210}Po contamination on the surfaces of the crystals and/or of the holder. As pointed out before, the distance between the two peaks is in good agreement with the expected recoiling energy of 103 keV and indicates a similar thermalization efficiency for α-particles and recoils. An accurate analysis of the time dependence of the counting rate of the smaller peak shows that only a tiny fraction of it decreases with the above mentioned lifetime. The main part remains constant thus indicating a different source for this ^{210}Po contamination. Other analysis of the α background shows that the surface contamination of ^{210}Po is out of secular equilibrium and comes probably from ^{222}Rn that quickly decays until it becomes ^{210}Pb.

The TeO_2 array is composed by four crystals held by a Teflon frame (see Fig. 2); this frame covers only a small fraction of the surface of the $6 \times 3\,cm^2$ faces of the detectors allowing the possibility to look for coincidences between pulses in different crystals.

To understand the origin of the surface contamination we have studied the coincidences between pulses in the 5304 keV peak in one detector and pulses in the two directly faced detectors of the array, calculating the ratio

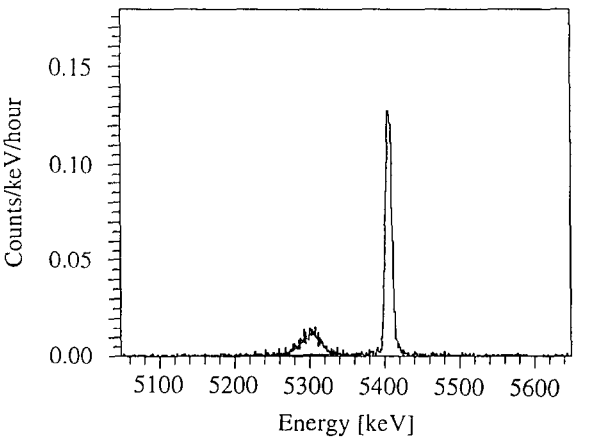

Fig. 1. Detail of the spectrum of the 3rd detector of the array in the energy region of the ^{210}Po α-lines.

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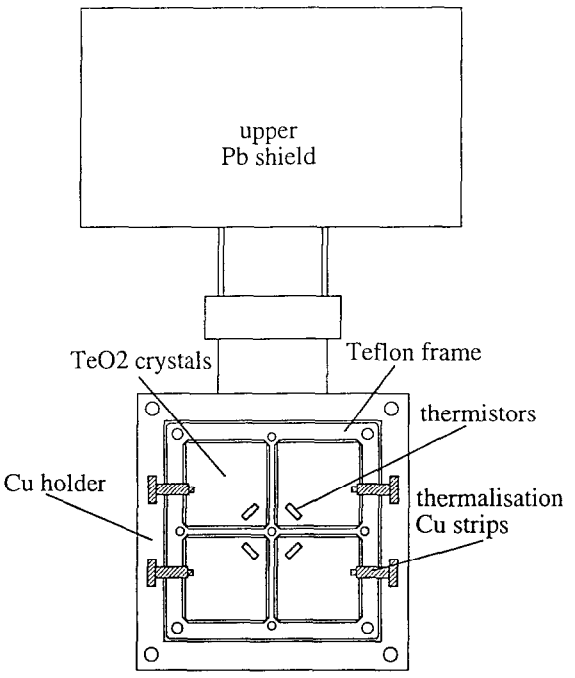

Fig. 2. Sketch of the mounting of the TeO_2 array.

between the number of pulses that give a coincidence and the total area of the peak.

The result clearly shows the 103 keV peak of the ^{123}Sb recoiling nucleus (see Fig. 3) confirming another time the effective thermalization of the recoil energy.

Taking into account the geometric efficiency a value of 121±26 counts is obtained for the α plus coincident recoil while the total area of 5304 keV peak is 540±45. Then only one fourth of the ^{222}Rn contamination comes from the surfaces of the crystals; the rest is on the surfaces of the holder.

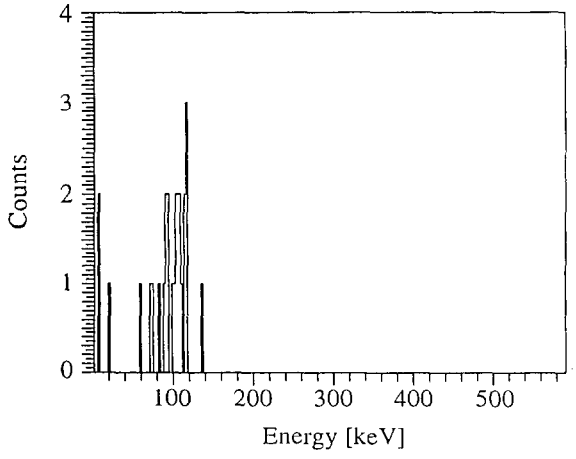

Fig. 3. Spectrum of the detector 4 obtained requiring coincidences with pulses in the 5304 keV peak on the detector 3.

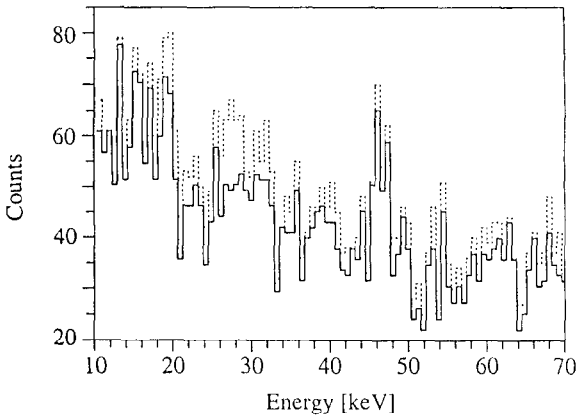

Fig. 4. Background spectrum of the detectors 4 in the energy region of the ^{123}Te decay with (solid line) and without (dashed line) the anticoincidence on the other detectors.

2. The decay of ^{123}Te

^{123}Te is a natural radioactive isotope with an isotopic abundance of 0.91%. It decays via electron capture mainly from the L shell:

$$^{123}\mathrm{Te} + \mathrm{e}^- \rightarrow {}^{123}\mathrm{Sb} + \nu_e \quad Q = 52\ \mathrm{keV},$$

$$\frac{1}{2}+ \rightarrow \frac{7}{2}+ \qquad \text{(second forbidden)}.$$

In the past, discordant results on the half-life were obtained [1,2]:

$$\tau_{1/2} = 1.34 \times 10^{13}\ \mathrm{yr} \quad \text{and} \quad \tau_{1/2} \geq 1.0 \times 10^{15}\ \mathrm{yr}.$$

We analysed the spectrum of the 4th detector of the array, that has $\Delta F_{\mathrm{FWHM}} \approx 3$ keV at 50 keV and a threshold of about 10 keV. Assuming that all the energy (except the neutrino energy) is collected, we looked at a peak at about 31 keV originated by the capture from the K shell. The energy released in a L capture, around 4 keV, is below our threshold. To avoid the contribution of the Te K_α (27 keV) we looked at the low energy spectrum of the detector requiring no pulses in the others. In Fig. 4 is clearly visible the decrease around 27 keV before and after the required anticoincidence. Considering the efficiency of the capture from the K shell $\varepsilon = 0.17\%$ and the duration of the measurement $T = 1548.4$ h, we have obtained:

$$\tau_{1/2} \geq 2.28 \times 10^{16}\ \mathrm{yr}\ (68\%\ \mathrm{c.l.}).$$

References

[1] J. Heinze, Z. Naturforsch. A 10 (1955) 77.
[2] Nuclear Data Sheets 29 (1980).