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## The Milano–Gran Sasso double beta decay experiment: toward a 20-crystal array

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### Abstract

TeO<sub>2</sub> thermal detectors are being used by the Milano group to search for neutrinoless double beta decay of <sup>130</sup>Te. An upper limit for neutrinoless decay half life of  $2.1 \times 10^{22}$  yr at 90% CL obtained with a 334 g TeO<sub>2</sub> detector has been previously reported.

To improve the sensitivity of the experiment an array of twenty 340 g TeO<sub>2</sub> crystals will be realised in the next future. As a first step toward the realisation of that experiment a 4 crystal detector has been tested in the Gran Sasso refrigerator. Detector performances, data acquisition and analysis are discussed.

### 1. Introduction

Since several years experimental physicists are looking toward the possibility that the Standard Model (SM) of electroweak interactions would not be complete. Among the several processes that could support this hypothesis is the process of neutrinoless double beta decay: this transition – which is energetically allowed for several isotopes – is forbidden in the theoretical frame of SM as it implies the violation of lepton number and the majorana character of neutrinos [1].

The advantages of using large mass, high resolution solid state detectors to search for 0ν-DBD have been largely discussed [2]. In this experimental approach the detector contains or is made of the isotope candidate to DBD and the signature of the decay is the appearance of a monochromatic line in the background spectrum, corresponding to the transition energy of the decay.

The application of this technique using conventional (ionisation) detectors has been made possible only for <sup>76</sup>Ge DBD experiments: the limit on 0ν-half life of <sup>76</sup>Ge obtained with germanium diodes is the highest ever reported [1]. New possibilities of exploiting this technique to search for 0ν-DBD of other isotopes are offered by thermal detectors.

Some years ago our group started working on the realisation of a <sup>130</sup>Te DBD experiment using bolometers.

The basic structure of our devices is the following: a NTD germanium thermistor is glued on a TeO<sub>2</sub> crystal, the former acting as a “thermometer” the latter acting as a “calorimetric mass” and – in the meantime – as a source of the decay to be searched. The kinetic energy lost inside the crystal by a moving particle is converted into heat producing a thermal signal that is transformed – by the constant-current biased thermistor – into an electrical pulse. The detectors are optimised to work at a temperature of about 10 mK to minimise heat capacity. They are operated in two <sup>3</sup>He/<sup>4</sup>He dilution refrigerators installed in the Underground Laboratories of Gran Sasso where a 1000 m rock overburden guarantees a remarkable reduction of cosmic rays. The contribution to background due to environmental radioactivity is strongly reduced by the lead shields surrounding the refrigerators.

We have already performed a first experiment with a 334 g TeO<sub>2</sub> detector having an energy resolution of 16.8 keV at the DBD transition energy (2828.8 keV), the background spectrum collected during 10 500 hours allowed us to set a lower limit of  $2.1 \times 10^{22}$  yr at 90% CL to 0ν-half life of <sup>130</sup>Te [3].

To improve the sensitivity reached in this experiment our group is now working in two directions. On one side – with the aim of reducing the background – we are accurately selecting low contamination materials to be used in the construction of the detector. On the other side – to have a larger number of DBD candidates – we are on the way to start a new experiment with an array of twenty 340 g TeO<sub>2</sub> bolometers.

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## 2. The future 20 element array and the status of the 4 element experiment

The single element of the array will be a 340 g  $\text{TeO}_2$  bolometer mounted inside a copper holder and held by a Teflon frame. NTD Ge thermistors with similar  $R(T)$  characteristics will be used, glued onto the crystals, as sensors. These have been chosen to operate the detectors at a base temperature of about 10 mK, having – at that temperature – a resistance of some hundred of  $\text{M}\Omega$ . Twenty similar detectors will be assembled together to form the array, each of them will be provided with its own bias circuit and read-out electronics [4].

The array will be mounted in the dilution refrigerator installed in hall A at LNGS and will be completely surrounded by a 3 cm thick lead shield, thermally connected to the 600 mK Still plate of the refrigerator. This shield is made with ancient roman lead whose contamination in  $^{210}\text{Pb}$  is extremely reduced; it will efficiently reduce gamma radiation deriving from the refrigerator itself and from the remnant radioactivity present in the external lead shields.

A 4 element prototype – very similar to the projected 20 element array – has been recently realised for test purposes. This device is presently running in hall A refrigerator yielding excellent results (see Fig. 1). In fact, while a reproducibility problem is responsible of a non-satisfactory performance of one of the bolometers, the other three detectors show quite good operation characteristics (see Table 1): their baseline fluctuation is of about 3 keV FWHM while their energy resolution is slightly worse. This difference between energy resolution and baseline width is mainly due to thermal instabilities (detector temperature variations of few percent are observed). The energy resolutions reported in Table 1 are evaluated on background spectra that have been “stabilised” with a software algorithm. This technique – described in the following – allows only to reduce but not to cancel the effects of thermal instability as it is evident

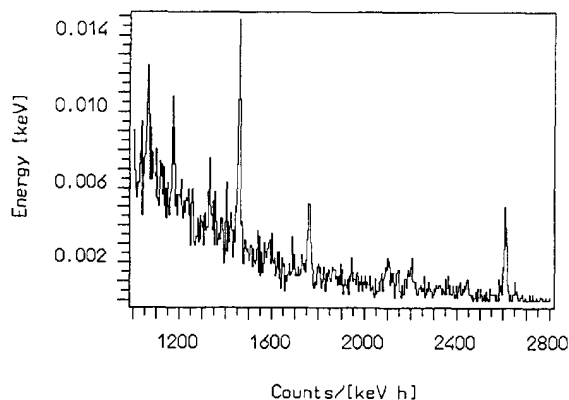


Fig. 1. Background spectrum of detector no. 4 of the array.

Table 1

Operating point parameters and energy resolutions for the 3 detectors of the array

	Detectors		
	2	3	4
Zero bias temperature [mK]	10.2	11.5	11
Load resistances [ $\text{G}\Omega$ ]	2	2.5	2
Operating point parameters			
Total bias [V]	0.630	2	0.11
Thermistor bias [mV]	7.4	5.5	22.8
Thermistor resistance [ $\text{M}\Omega$ ]	23.6	6.9	524
Thermistor temperature [mK]	13	15.2	15.1
Pulse heights at 2.6 MeV [mV]	0.27	0.15	2.4
Energy resolution (FWHM)			
at 100 keV [keV]	4	5	3
at 2.6 MeV [keV]	9	12	11

from the worsening of the resolution with increasing energy.

To remove the origin of this problem we plan to thermally decouple the holder of the detectors from the mixing chamber of the refrigerator by means of a Vespel joint, using a feedback controlled system to stabilise the temperature of the holder itself. We are also studying more reliable procedures for detector mounting and wiring, not only to ensure a good reproducibility but also to solve the problem of thermal and electrical cross talk (now observed).

## 3. Data acquisition and analysis

Data acquisition, consisting in the background spectrum measurement, is performed by digitising and saving the wave forms of all signals that have passed the trigger threshold. The signals are DC coupled so that the baseline value, obtained from the pre-trigger data prior to each pulse, provides a measurement of detector bias and temperature at the very instant in which the pulse has arrived. Recently our group has developed a VXI data acquisition system to substitute the previously used CAMAC one. This system, especially projected for the 20 bolometer experiment, allows data acquisition on several channels having independent triggers and independent sampling times each. Moreover it guarantees a fast data recording reducing the problem of dead time. An off-line software analysis based on the optimum filtering technique is then used to calculate the heights of the triggered signals. This technique allows also to construct wave form discrimination algorithms that are used to reject all spurious signals such as electrical spikes, microphonic produced pulses and electrical cross talk.

To reduce the effects of thermal fluctuations on energy resolution the spectra are “stabilised” on the basis of the

monochromatic alpha line of  $^{210}\text{Po}$  (an internal contamination existing in all our crystals). From the amplitude vs. baseline and amplitude vs. time behaviours of the alpha signals it is possible to determine a relationship between the pulse heights and either the baseline value or the time of arrival of the signals. With this method the amplitude of each signal is corrected according to its baseline value and its arrival time. As they operate on a large dynamical range our detectors have a non-linear response that makes the energy linearisation of the spectra necessary. The recognised gamma lines present in the background are used to calibrate and linearise the spectra. A maximum likelihood procedure is then used for DBD analysis.

#### 4. Conclusions

No evidence of  $0\nu\text{-DBD}$  is present in the 1800 hours background spectra collected until now with the three working detectors of the array. A lower limit of  $2.39 \times 10^{22}$  yr (at 90% CL) to  $^{130}\text{Te}$   $0\nu$ -half life is obtained by combining the spectra of the 3 working elements of the array together with the single 334 g detector spectrum. The experiment with this prototype is still running to collect more information concerning the origin of the background present in the  $0\nu\text{-DBD}$  region.

The 20 crystal array experiment should start during 1996. In the pessimistic assumption that background counting rates similar to the ones now measured will be obtained, a sensitivity of the order of  $10^{23}$  years would be reached in one year running time.

A further improvement in the sensitivity will be obtained using the  $^{130}\text{Te}$  enriched crystals which are being grown in China (SIC) with the enriched material prepared by the Kurchatov Institute (Moscow).

#### References

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