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First results from the Cuoricino experiment

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Abstract

At the end of 2001 the Milano Double Beta Decay (MI-DBD) experiment on double beta decay of ^{130}Te has been completed. The project Cryogenic Underground Observatory for Rare Events (CUORE), proposed as a natural extension of MI-DBD, will be a tightly packed array of 1000 TeO_2 bolometers, each being a cube 5 cm on a side with a mass of 790 g. The array will consists of 25 vertical towers, arranged in a square of 5 towers by 5 towers, each containing 10 layers of 4 crystals. A single CUORE tower has been constructed as a smaller scale experiment called CUORICINO. The technical feasibility of CUORE is now being tested in CUORICINO, running since few weeks. The CUORICINO experiment consists of 44 TeO_2 detectors $5 \times 5 \times 5\,cm^3$ and 18 TeO_2 detectors $3 \times 3 \times 6\,cm^3$ for a total mass of approximately 41 kg. An analysis of the detector performances is presented together with the new limit obtained on neutrinoless double beta decay of ^{130}Te.

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1. Introduction

Double beta decay (DBD) consists in a rare transition from the nucleus (A,Z) to its isobar (A,$Z+2$) with the emission of two electrons. It can be revealed when the transition from (A,Z) to (A,$Z+1$) is energetically forbidden or at least strongly hindered by a large change of angular momentum. Two-neutrino double beta decay, where two anti-neutrinos are emitted together with the two electrons, conserves the lepton number, is predicted by the standard weak interaction theory and has been observed for several nuclei. If lepton number is violated, the two electrons could be emitted without any other particle. This process, called neutrinoles double beta decay (0ν-DBD), would have obvious implications in Gran Unified and Supersimmetric theories.

2. Experimental details

The Cuoricino experiment, operating in the Hall A of the Gran Sasso Underground Laboratory, is a natural extension of the Milano Double Beta Decay experiment, completed in 2001 [1]. Cuoricino consists in a tower with 13 layers (see Fig. 1) of which 11 layers are realized with 4 TeO_2 crystals of $5\times5\times5\,cm^3$ (790 g), while 2 layers are composed by 9 TeO_2 crystals of $3\times3\times6\,cm^3$ (330 g) for a total mass of about 41 kg.

The crystals are fastened to a copper structure by means of PTFE supports. The temperature sensors are Neutron Transmutation-Doped germanium thermistors glued on a face of the detectors. A resistor of 50–100 kΩ, realized with a heavily doped meander on a 1 mm^3 silicon chip is also attached to each adsorber and acts as an heater to calibrate and stabilize the gain of the bolometer [2].

The tower is mechanically connected to the still plate with a stainless-steel spring that acts as a vibrations dumper.

The thermal connection is realized with 50 μm thick copper strips connected between the cold finger and the mixing chamber.

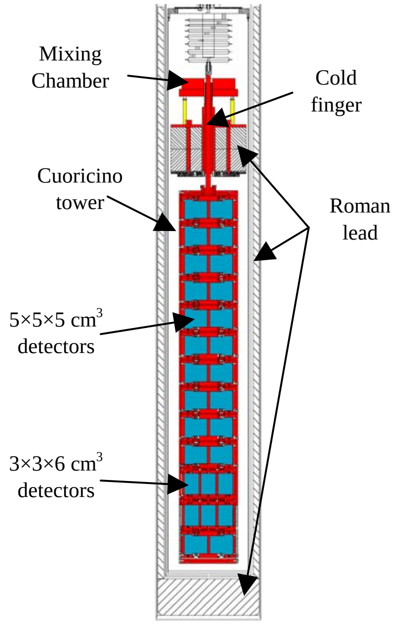

Fig. 1. Scheme of the Cuoricino tower inside the dilution refrigerator.

The dilution refrigerator was specially constructed with previously tested low radioactive materials. Nevertheless inside the 4 K thermal shield, a layer of ancient roman lead, of minimum thickness of 2 cm, was put in order to shield the detectors from the residual radioactivity of the cryostat.

The entire set-up is shielded against external radioactivity by a layer of lead of 20 cm minimum thickness and by a 10 cm borated polyethylene. In addition the cryostat is surrounded by a sealed box continuously flushed with nitrogen in order to avoid radon background.

3. Detector performances

Due to a problem in the thermalization stages of the wires, during the cooldown 13 detectors were lost. However, the remaining bolometers show good perfomances. The average pulse height is about 440 μV/MeV for the $5\times5\times5\,cm^3$ crystals and 340 μV/MeV for the $3\times3\times6\,cm^3$ crystals.

The array has been calibrated exposing it to a ^{232}Th radioactive source; the FWHM energy

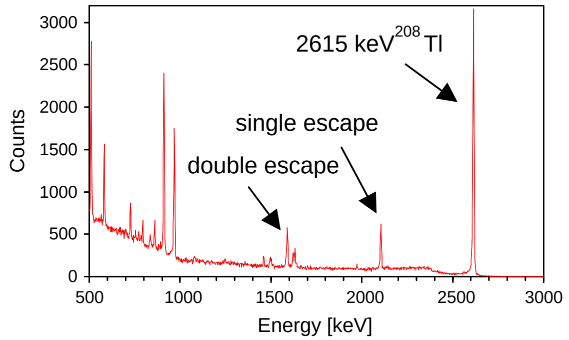

Fig. 2. Sum spectrum of all the $5 \times 5 \times 5\,cm^3$ crystal obtained during a ^{232}Th calibration.

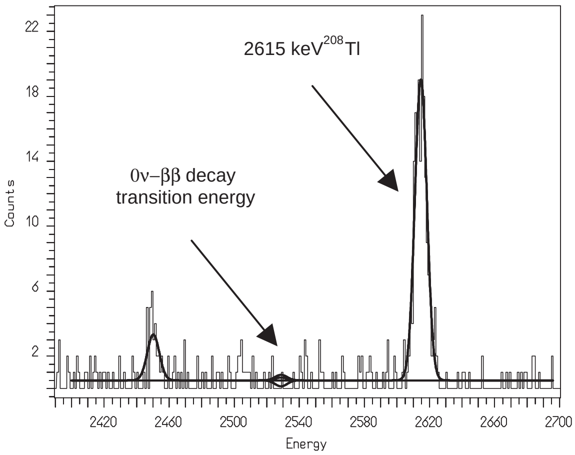

Fig. 3. Total background spectrum (in anticoincidence between the detectors) in the region of neutrinoless DBD of ^{130}Te. The solid curves represent the best fit (lowest) and the 68% and 90% CL excluded signals.

resolution at 2615 keV ranges between 4 and 20 keV with an average of 7 and 9 keV, respectively, for the 790 g and the 330 g detectors. The good uniformity of the detectors is obvious, looking at the sum spectrum of the $5 \times 5 \times 5\,cm^3$ crystals (Fig. 2).

4. Physics results

The good performances of Cuoricino allowed, in slighty more than a month of data collection (2.26 kgxy), to improve the previous results.

No evidence was found for neutrinoless double beta decay of ^{130}Te with a 90% CL lower limit of 5.0×10^{23} years (Fig. 3); this corresponds to an upper limit on the effective neutrino mass $\langle m_0 \rangle$ ranging from 0.7 to 1.7 eV, depending on the various theoretical calculations of the nuclear matrix elements.

Beyond the physics results, Cuoricino is also a test of feasibility of a bigger experiment [3] called Cryogenic Underground Observatory for Rare Events that will be composed by 1000 TeO_2 detectors for a total mass of about 0.8 ton.

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