CUORE EXPERIMENT: THE SEARCH FOR NEUTRINOLESS DOUBLE BETA DECAY

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The main purpose of the Cryogenic Underground Observatory for Rare Events (CUORE) experiment is the search for the Neutrinoless Double Beta Decay (0νDBD) of ^{130}Te reaching a sensitivity on Majorana mass better than 50 meV. Cuoricino represents not only the first stage of CUORE, but also the most massive 0νDBD experiment presently running. Present results and future planning of these experiments will be described in the paper.

Keywords: Double beta decay; neutrino; bolometer; cryogenic detector.

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1. The Neutrinoless Double Beta Decay

The search for 0νDBD has become one of the top priorities in the field of neutrino physics since the discovery of neutrino oscillations in atmospheric, solar, and reactor experiments. This rare nuclear transition could prove the Majorana character of neutrinos (as foreseen by the majority of theories) allowing in the meantime to obtain information on the neutrino mass hierarchy and scale. A number of experiments are currently at various stages of development to probe the degenerate mass hierarchy region of the neutrino mass spectrum and the inverted hierarchy[1]. The signature of the 0νDBD is very clear as it is a peak in the sum energy of the two electrons: however, due to its very long half time, the detection is also a very challenging goal. The musts of experiments that are serching for evidence of this rare decay are: 1) to work with very large source masses, of order one ton or larger; 2) to use detectors with good energy resolution and high efficiency in order to improve the signal to background ratio in the search for the peak; this is important also because the 2νDBD spectra would be a source of dangerous background for the 0νDBD peak; 3) to perform the experiment in very radiopure conditions and in an underground laboratory in order to avoid natural and cosmogenic background; 4) to have long data taking periods.

2. CUORE and Cuoricino experiments

The CUORE experiment [2] will be placed in the hall A of the Gran Sasso Underground Laboratory. This nucleus is a good candidate as source of the decay as its Q-value (at 2530 keV) is in an energy window with in principle low background, between the full peak and the Compton edge of the ^{208}Tl gamma line; moreover the ^{130}Te has a high natural abundance (33,8%, more than three times the natural abundance of other elements candidate to 0νDBD): this allows to have huge source quantities without recurring to the enrichment option. The CUORE detector is a system of 988 bolometers, each being a cube of 5x5x5 cm^3; the array is composed by 19 vertical towers. Each tower consists of 13 layers of 4 cubes each. The single cube will be a crystal of TeO_2. The total mass of the detector will be 741 kg of granular calorimeter, corresponding to 600 kg of Te, and to 203 kg of ^{130}Te. In bolometers, the deposited energy is measured thermally. The energy released in a single particle interaction within the crystal is clearly measurable as a change in temperature of the entire crystal. The temperature change is measured by Neutron Transmutation Doped (NTD) germanium thermistors. The bolometers of CUORE will work at about 10 mK in a new big dilution refrigerator built with low radioactive materials. The detector assembly will start in 2008 and the data taking is planned to start during 2011.

Cuoricino [3] is the biggest running 0νDBD experiment. The first Cuoricino measurement started in March 2003 and ended in October 2003. After a substantial operation of maintenance in April 2004, the second run of Cuoricino started. The Cuoricino detector has a tower-like structure that uses 40 kg of TeO_2. The array is composed by 44 crystals of 5x5x5 cm^3 size and 760 g weight and 18 crystals of 3x3x6 cm^3 size and 340 g weight placed arranged in 13 elementary modules. A picture of the Cuoricino detector is shown in Fig. 1 (left).

3. Experimental results and future prospects

The average resolution FWHM obtained with the crystals of Cuoricino is 7.5±2.9 keV for the big size bolometers and 9.6±3.5 keV for the small ones. The current

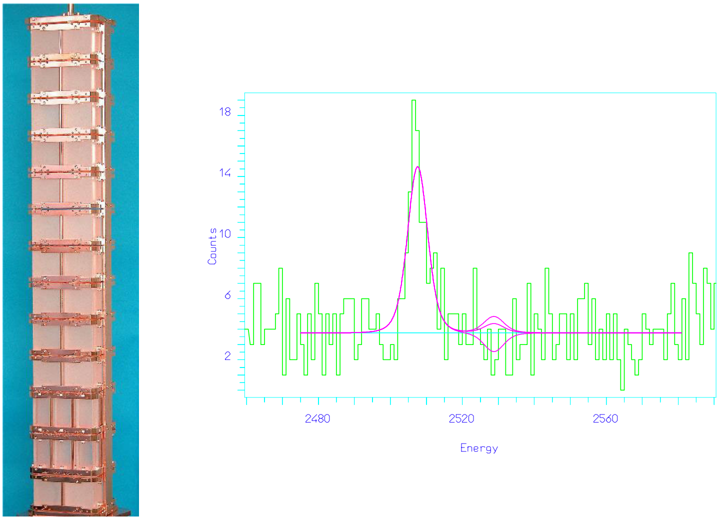

Fig. 1. (Left) Picture of the Cuoricino detector. (Right) Background in the 0νDBD region collected with Cuoricino.

background in the 0νDBD region is 0.18 ± 0.02 c/keV/kg/y and is shown in Fig. 1 (right). Cuoricino is presently giving a limit of 3.0×10^{24} years at the 90 % C.L. on $T^{0\nu}_{1/2}$, corresponding to a bound on $\langle m_\nu \rangle$ between 0.2 and 0.98 eV depending on nuclear matrix models. The double decay region Cuoricino experiment is not only a powerful experiment that is giving important results on DBD but it is also a good instrument to obtain information in view of the CUORE project. Montecarlo simulations made by the CUORE collaboration indicate that the main and most dangerous components of the Cuoricino background is due to energy degraded alphas coming from surface contaminations of the materials surrounding the bolometers, such as the copper frames that hold the TeO_2 crystals. The collaboration is studying passive and active methods in order to reduce this background contribution in the CUORE detectors. In a conservative hypothesis about background (0.01 c/keV/kg/y) and with 10 keV energy resolution, CUORE should obtain in 10 years of data taking a sensitivity on the half life of 0νDBD of 2.1 10^{26} years corresponding to a neutrino mass limit ranging between 20 and 160 meV. In an optimistic hypothesis regarding the background (0.001 c/keV/kg/y) with 5 keV energy resolution and 5 years of data taking, CUORE is foreseen to have a sensitivity on the half life of 0νDBD of 6.5 10^{26} years and a neutrino mass limit of 10-60 meV.

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