# NEUTRINOLESS DOUBLE BETA DECAY SEARCH WITH CUORICINO AND CUORE EXPERIMENTS.

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**Abstract:** CUORICINO is a bolometric experiment on Neutrinoless Double Beta Decay ($0\nu$-DBD) . With its 40.7 kg mass of $TeO_2$ it is the most massive $0\nu$-DBD presently running and it has proven the feasibility of the CUORE experiment, whose aim is to be sensitive to the effective neutrino mass down to few tens of meV. We report here latest CUORICINO results and prospects for the future CUORE experiment.

**Keywords:** ***neutrino, majorana, double beta decay, bolometer.***

## INTRODUCTION

The positive results obtained in the last few years in neutrino oscillation experiments have given convincing and model indipendent evidences that neutrinos are massive and mixed particles. The obtained data are compatible with two possible mass patterns, or hierarchies, the normal: $m_1 < m_2 \ll m_3$, and the inverted hierarchy: $m_3 \ll m_1 < m_2$. Unfortunately oscillation experiments are only sensitive to neutrino mass squared differences and cannot give any information about neutrino nature (Dirac or Majorana particle) and absolute mass scale. Beta decay experiments are sensitive to the absolute mass scale but cannot determine neutrinos nature. Experiments looking for the Neutrinoless Double Beta Decay ($0\nu$-DBD) of even-even nuclei have the highest sensitivity to the effective neutrino mass ($m_{\beta\beta}$) and to the neutrino nature. A positive signal would imply that neutrino are Majorana particles and can even lead to the measure of the absolute mass scale.

The use of the bolometric technique offers the unique possibility to investigate different $0\nu$-DBD candidates with a considerable high energy resolution, needed to separate the $2\nu$ contribution from the $0\nu$ peak. The CUORE experiment [1], to search $0\nu$-DBD of $^{130}$Te, will start its assembling phase in 2008 and it aims to reach a sensitivity on $m_{\beta\beta}$ better than 50 meV. CUORICINO [2] represent not only the first stage of CUORE, but also the most massive $0\nu$-DBD Experiment presently running.

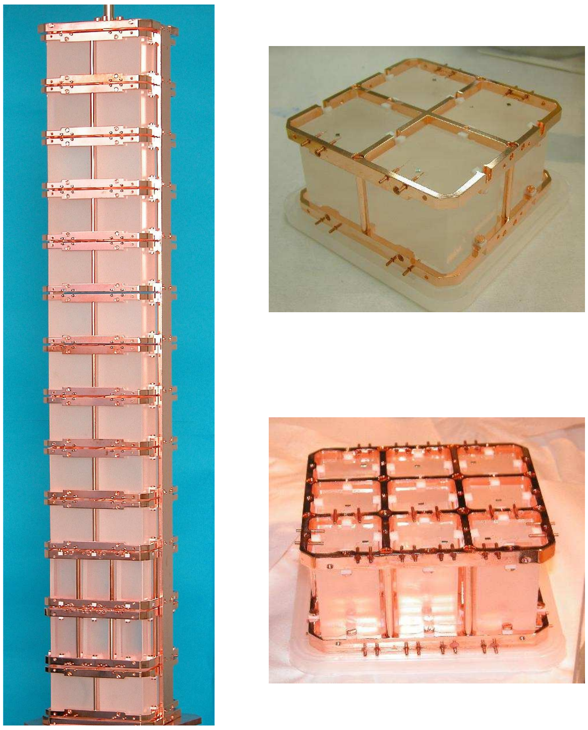

Figure 1: CUORICINO array (left) and details of the planes hosting the $5 \times 5 \times 5$ cm$^3$ crystals (top right) and $3 \times 3 \times 6$ cm$^3$ crystals (bottom right)

## CUORICINO SETUP

CUORICINO is an array of 62 crystals of $TeO_2$ with a total active mass of 40.7 kg, that corresponds to a mass of $^{130}$Te of $\sim$ 11 kg. The tower is located inside the cryostat situated in the Hall A of Laboratori Nazionali del Gran Sasso (LNGS) of INFN. CUORICINO's 62 crystals are arranged in a tower made by 13 planes (Figure 1), 11 of them are filled with 4 cubes of 5 cm side while the other two with 9 crystals $3{\times}3{\times}6$ cm$^3$ each. Four $3{\times}3{\times}6$ cm$^3$ crystals are enriched, two of which in $^{128}$Te, 82.3 % isotopic abundance, and the other two in $^{130}$Te, isotopic abundance of 75 %.

All the materials composing the detector were selected to be low contaminated with radioactive isotopes. To avoid external vibrations to reach the detectors the tower is mechanically decoupled from the cryostat through a steel spring. In order to shield against the radioactive contaminants from the materials of the refrigerator, a 1.2 cm shield of Roman lead with $^{210}$Pb activity less than mBq/kg is framed around the array to reduce the activity of the thermal shields. The cryostat is externally shielded by means of two layers of lead of 10 cm minimal thickness each. The background due to environmental neutrons is reduced by a layer of Borated Polyethylene of 10 cm minimum thickness. The refrigerator operates inside a Plexiglas anti-radon box flushed with clean $N_2$ and inside a Faraday cage to reduce electromagnetic interferences. Thermal pulses are recorded by neutron transmutation doped Ge thermistors thermally coupled to each crystal. CUORICINO is operated at a temperature of $\sim$ 8 mK with a spread of $\sim$ 1 mK. The energy calibration is performed before and after each subset of runs, which lasts about a month, by exposing the array to two thoriated tungsten wires inserted in immediate vicinity of the refrigerator.

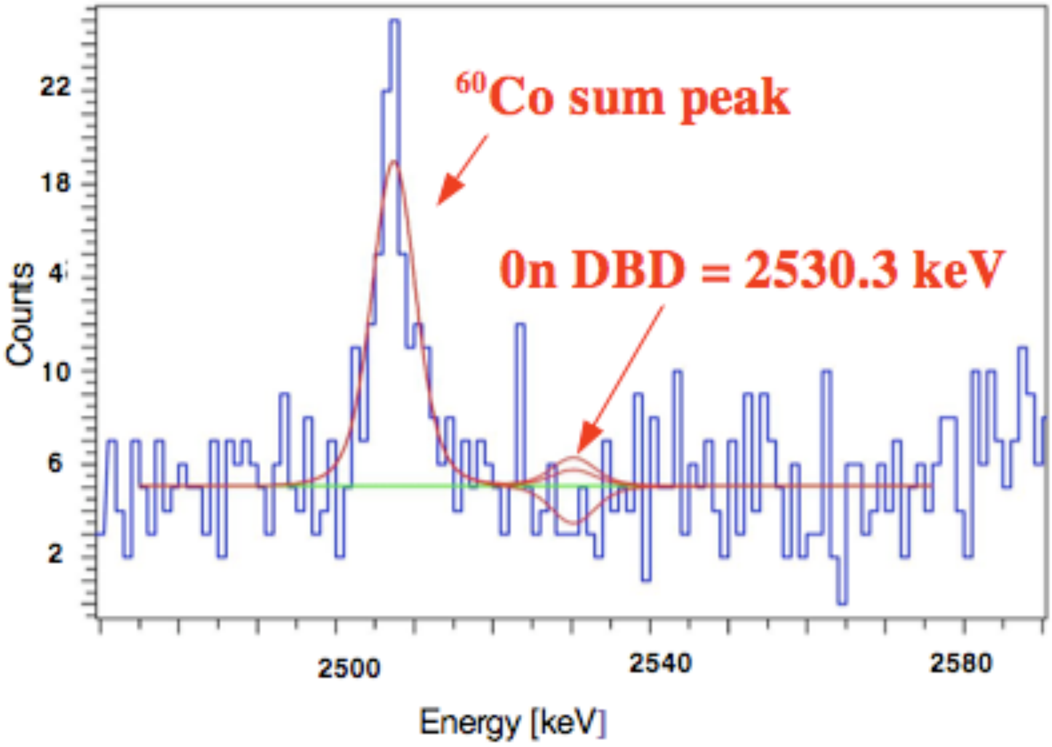


Figure 2: CUORICINO spectrum in the $0\nu\beta\beta$ region

## CUORICINO RESULTS

CUORICINO first measurement started in March 2003 and ended in of October 2003. After a substantial operation of maintenance in April 2004 the second run of CUORICINO started. The average resolution FWHM is 7.5 $\pm$ 2.9 keV for the bigger size and of 9.6 $\pm$ 3.5 keV for the small size crystals. The duty cycle of the experiment, since August 2004 is $\sim$ 73 %. Discarding the time needed for energy calibration measurement (3 days every 3–4 weeks) the total live time is 63 %. The background spectra collected up to May 2006, corresponding to a total statistic of 8.38 kg ($^{130}$Te) $\cdot$year , is presented in figure 2. Apart the $^{60}$Co sum line, no other unexpected peak if found near the 2528 keV $0\nu$DBD region of $^{130}$Te. The corresponding lower limit on the $0\nu$DBD of $^{130}$Te is of 2.4$\times$ $10^{24}$ y (90% C.L.). This limit leads to a constraint on the electron neutrino effective Majorana mass ranging from 0.18 to 0.97 eV, depending on the nuclear matrix elements considered in the computation.

## THE CUORE EXPERIMENT

The CUORE detector will consist of an array of 988 $TeO_2$ bolometers arranged in a cylindrical configuration of 19 towers containing 52 crystals each (Figure 3), for a total mass of $\sim$741 kg. Each of these towers is a CUORICINO-like detector consisting of 13 modules, 4 detectors each. Assuming a background of B=0.01 c/keV/kg/y, achievable with a slight improvement of the current available material selection and cleaning techniques, and an energy resolution $\Gamma$(2.5 MeV)=5 keV, we get a sensitivity $S_{0\nu}$ on the half life (90 % C.L.) of 5.8$\cdot$ $10^{25}\sqrt{t}$ years (4.1$\cdot$ $10^{25}\sqrt{t}$ years for $\Gamma$=10 keV), which in 5 years of statistics would provide $m_{\beta\beta}$ bounds in the

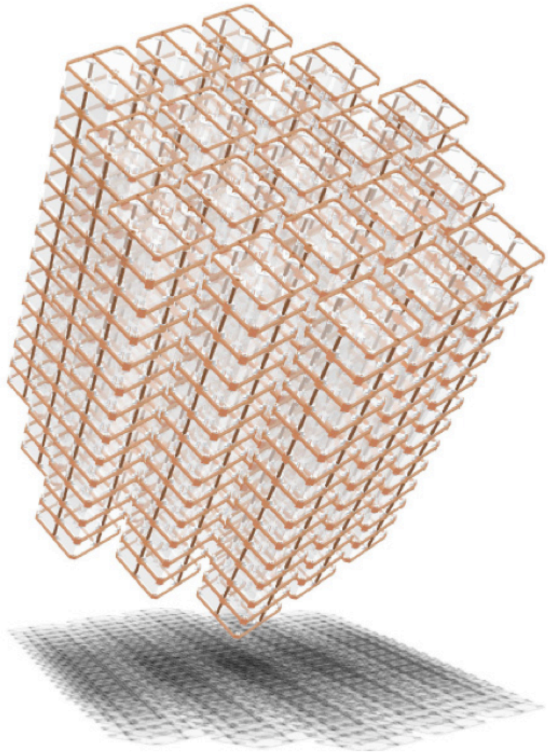

Figure 3: CUORE detector: the bolometers array is made of 19 CUORICINO like towers

range 0.024–0.13 eV. However, the R&D to be carried out in CUORE, if successful, would provide a value of B$\sim$ 0.001 c/keV/kg/y, i.e. a detection sensitivity of $S_{0\nu}\sim$ 1.86$\cdot$ $10^{26}\sqrt{t}$ years (1.2$\cdot$ $10^{26}\sqrt{t}$ years for $\Gamma$=10 keV), or $m_{\beta\beta}$ bounds in the range $\sim$ 0.016–0.085 eV in 5 years. $TeO_2$ crystals made with $^{130}$Te enriched material have been already operated in MiDBD and CUORICINO, making an enriched CUORE a feasible option. Assuming a 95% enrichment in $^{130}$Te and a background level of B=0.001 c/keV/kg/y, the sensitivity would become $S_{0\nu}\sim$ 8.32$\cdot$$10^{26}\sqrt{t}$ years. For an exposure of 5 years, the corresponding $m_{\beta\beta}$ bounds would range from 8 meV to 45 meV depending on the nuclear matrix element calculations.

## References


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