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Abstract. The CUORE-0 experiment searched for neutrinoless double beta decay in ^{130}Te using an array of 52 tellurium dioxide crystals, operated as bolometers at a temperature of 10 mK. It took data in the Gran Sasso National Laboratory (Italy) since March 2013 to March 2015. We present the results of a search for neutrinoless double beta decay in 9.8 kg·years ^{130}Te exposure that allowed us to set the most stringent limit to date on this half-life. The performance of the detector in terms of background and energy resolution is also reported.

1. Introduction

Neutrinoless double-beta ($0\nu\beta\beta$) decay is an hypothesized nuclear decay that violates lepton number conservation. In this transition a nucleus (A, Z) decays into (A, Z+2) nucleus with the emission of two electrons and no neutrino, resulting in a peak in the sum energy spectrum of the emitted electrons. This process, first hypothesized by Pontecorvo in 1967 [1], has never observed so far. Its discovery would demonstrate the lepton number violation, the Majorana nature of neutrinos and would constrain the absolute neutrino mass scale. Given its importance, an intense experimental effort is ongoing to search for this decay in several nuclei [2, 3, 4].

The Cryogenic Underground Observatory for Rare Events (CUORE) [5], presently in the final stages of construction at the Gran Sasso National Laboratory (LNGS), will be one of the most sensitive upcoming $0\nu\beta\beta$-decay experiments. It is an array of 988 TeO_2 low-temperature calorimeters with the goal of searching for the $0\nu\beta\beta$ decay of ^{130}Te. The detectors are arranged in a compact structure of 19 towers, each one containing 52 TeO_2 crystals, arranged on 13 floors. CUORE has been designed on the experience of the predecessor experiment Cuoricino [6]. It was a single tower of 62 bolometers ($\sim$40 kg of TeO_2) which ran in the LNGS from 2003 to 2008. Cuoricino did not observe any evidence for the $0\nu\beta\beta$ decay of ^{130}Te and set a limit on its hals file of $T_{0\nu} > 2.8\times10^{24}$ yr (90% C.L.) [7]. Scaling from Cuoricino to CUORE, we aim to improve the sensitivity to the $0\nu\beta\beta$ half life of ^{130}Te. This goal can be achieved by increasing the exposure (increasing the active mass) and by reducing the background in the Region Of Interest (ROI), using an improved material selection, cleaning and handling procedures. Before starting the construction of the 19 CUORE towers, an additional tower, named CUORE-0, was produced according to the CUORE requirements.

2. The CUORE-0 experiment

CUORE-0 is a single CUORE-like tower, the first one built using the low-background assembly techniques developed for CUORE [8]. It is made of 52 TeO_2 bolometers, for a total mass of 39 kg. The TeO_2 crystals are held in an ultra-pure copper frame by Polytetrafluoroethylene (PTFE) supports and they are arranged in 13 floors, with 4 crystals per floor (see Fig. 1). Each TeO_2 detector is instrumented with a Neutron Transmutation Doped (NTD) Ge thermistor glued on its surface, to measure the temperature change of the absorber and convert it into an electric signal. Each crystal is instrumented also with a silicon resistor ("heater") to generate reference pulses. A custom design semi-automated system was developed in order to reproduce the mechanical coupling between the crystals and the chips, namely the glue. The results on the detector performance uniformity serves as evaluation parameters for validating the system operations. The tower was operated in Hall A of LNGS, in the same dilution refrigerator that previously hosted the Cuoricino experiment, and it took data between March 2013 and March 2015. Technical details are reported in [9], while the CUORE-0 physics results can be found in [10].

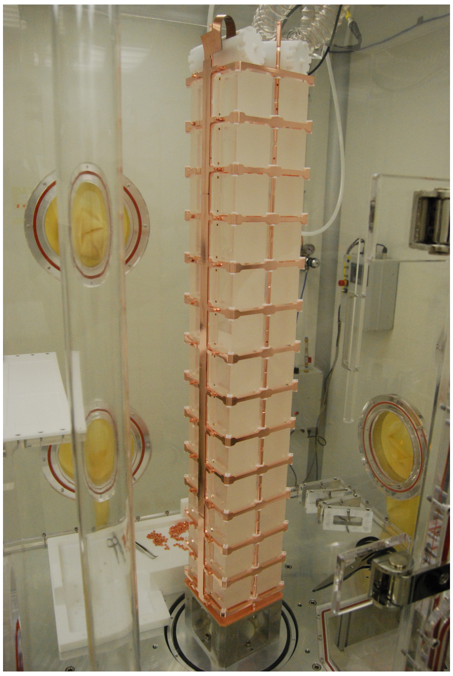

Figure 1. Picture of the CUORE-0 detector: the 52 TeO_2 crystals are arranged in 13 floors of 4 crystals each.

2.1. Thermistor uniformity

One of the CUORE-0 goals was to test, and compare, the major upgrades in the uniformity of the bolometric performance achieved with the new CUORE-style assembly line, with respect to its predecessor Cuoricino.

Figure 2 shows the comparison of the bolometric performance of CUORE-0 and Cuoricino. The RMS of the base temperature distributions (lowest detector temperature) is evaluated to be 9% for the Cuoricino detector while for CUORE-0 is 2%. The narrower distribution of CUORE-0 temperatures compared to the Cuoricino ones is a demonstration of the efficient operation of the semi-automated system for the sensor-to-absorber coupling.

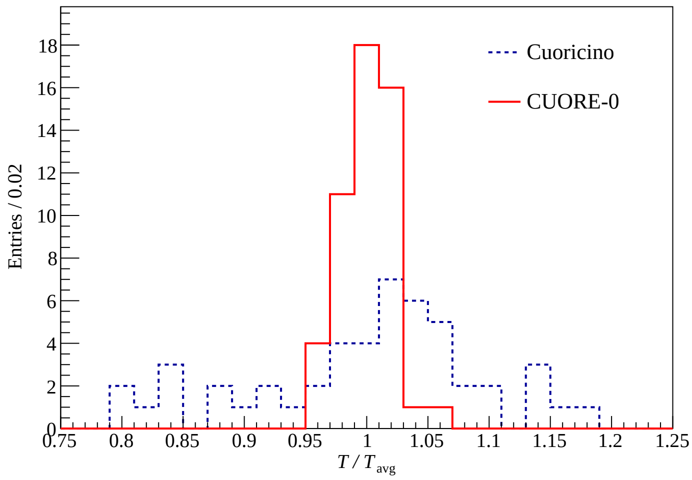

Figure 2. Comparison of the base temperatures of the CUORE-0 (red solid line) and Cuoricino (blue dashed line) bolometers normalized to the average temperature of the whole detectors.

2.2. Detector performance
CUORE-0 acquired data for $0\nu\beta\beta$ search accumulating a total exposure of 9.8 kg·y of ^{130}Te. Data are collected in month-long blocks called datasets. At the beginning and end of each dataset we calibrate the detector by placing a ^{232}Th source next to the outer vessel of the cryogenic system. We use the calibration line with the highest intensity and next to the ROI, 2615 keV from ^{208}Tl, in order to study the detector response function to a mono energetic energy deposit for each bolometer and dataset. We estimate the shape parameters of the 2615 keV line with a simultaneous, unbinned extended maximum likelihood (UEML) fit to calibration data. The physics- exposure-weighted effective mean of the FWHM values for each bolometer and dataset is 4.9 keV, with a corresponding RMS of 2.9 keV. We evaluate the background level in the alpha-dominated region (2700-3900) keV to be 0.016±0.001 counts/(keV·kg·y), 6 times smaller with respect to the Cuoricino background in the same region.

2.3. $0\nu\beta\beta$ decay result
We search for $0\nu\beta\beta$ decay of ^{130}Te in the final CUORE-0 energy spectrum performing a simultaneous UEML fit in the energy region 2470-2570 keV (Fig. 3). The fit function is composed by three parameters: a posited signal peak at the Q-value of the transition, a peak at $\sim$2507 keV from ^{60}Co double-gammas, and a smooth continuum background attributed to multi-scatter Compton events from ^{208}Tl and surface decays. The best-fit values are $\Gamma_{0\nu} = 0.01 \pm 0.12(\text{stat}) \pm 0.01(\text{syst}) \times 10^{-24}\text{yr}^{-1}$ for the $0\nu\beta\beta$ decay rate and 0.058±0.004(stat)±0.002(syst) counts/(keV·kg·y) for the background index in the ROI. This result is 3 times lower than the Cuoricino background, 0.169±0.006 counts/(keV·kg·y), in the same ROI. Using a Bayesian approach, we set a 90% C.L. lower bound on the decay half-life of 2.7×10^{24}yr [10]. When combined with the 19.75 kg·y exposure of ^{130}Te from the Cuoricino experiment, we find a

Bayesian 90% C.L. limit of $T_{0\nu} > 4.0 \times 10^{24}$yr which is the most stringent limit to date on the ^{130}Te $0\nu\beta\beta$ half-life. Additional details on the analysis techniques can be found in [11].

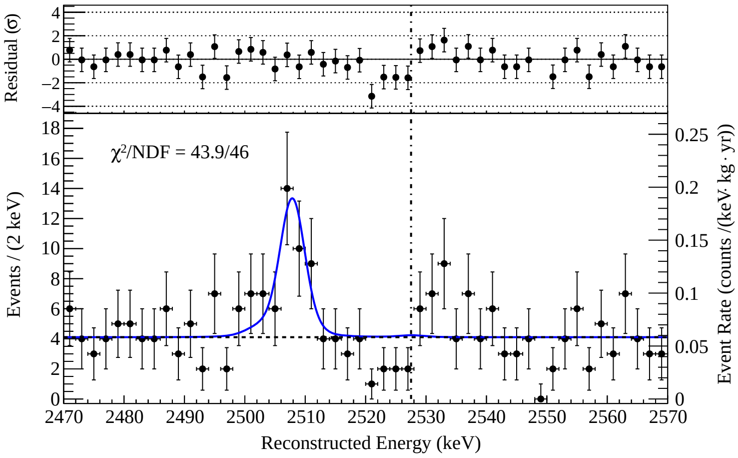

Figure 3. The best-fit model from the UEML fit (solid blue line) overlaid on the spectrum of $0\nu\beta\beta$ decay candidates in CUORE-0 (data points). The vertical dot-dashed black line indicates the position of Q-value. Top: The normalized residuals of the best-fit model and the binned data.

2.4. Acknowledgments

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