CUORE experiment

CUORE collaboration

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Abstract. CUORE is a ton scale bolometric experiment for the search of neutrinoless double beta decay in ^{130}Te. The detector started taking data in April 2017 at the Laboratori Nazionali del Gran Sasso of INFN, in Italy. The projected CUORE sensitivity for the neutrinoless double beta decay half life of ^{130}Te is of $9{\times}10^{25}$ y after five years of live time. In 2018 the CUORE computing and storage resources at CNAF were used for the data processing and for the production of the Monte Carlo simulations used for a preliminary measurement of the 2ν double-beta decay of ^{130}Te.

1. The experiment

The main goal of the CUORE experiment [1] is to search for Majorana neutrinos through the neutrinoless double beta decay (0νDBD): $(A, Z) \rightarrow (A, Z{+}2){+}2e^{-}$. The 0νDBD has never been observed so far and its half life is expected to be higher than 10^{25} y. CUORE searches for 0νDBD in a particular isotope of Tellurium (^{130}Te), using thermal detectors (bolometers). A thermal detector is a sensitive calorimeter which measures the energy deposited by a single interacting particle through the temperature rise induced in the calorimeter itself. This is accomplished by using suitable materials for the detector (dielectric crystals) and by running it at very low temperatures (in the 10 mK range) in a dilution refrigerator. In such condition a small energy release in the crystal results in a measurable temperature rise. The temperature change is measured by means of a proper thermal sensor, a NTD germanium thermistor glued onto the crystal. The bolometers act at the same time as source and detectors for the sought signal. The CUORE detector is an array of 988 $^{nat}TeO_2$ bolometers, for a total mass of 741 kg (206 kg of ^{130}Te). The bolometers are arranged in 19 towers, each tower is composed by 13 floors of 4 bolometers each. A single bolometer is a cubic TeO_2 crystal with 5 cm side and a mass of 0.75 kg. CUORE will reach a sensitivity on the ^{130}Te 0νDBD half life of 9×10^{25} y. The cool down of the CUORE detector was completed in January 2017, and after a few weeks of pre-operation and optimization, the experiment started taking physics data in April 2017. The first CUORE results were released in summer 2017 and were followed by a second data release with an extended exposure in autumn 2017 [2]. The same data release was used in 2018 to produce a preliminary measurement of the 2-neutrino double-beta decay [3]. In 2018 CUORE acquired less than two months worth of physics data, due to cryogenic problems that required a long stop of the data taking.

2. CUORE computing model and the role of CNAF

The CUORE raw data consist in Root files containing the continuous data stream of $\sim$1000 channels recorded by the DAQ at sampling frequencies of 1 kHz. Triggers are implemented via software and saved in a custom format based on the ROOT data analysis framework. The non event-based information is stored in a PostgreSQL database that is also accessed by the offline data analysis software. The data taking is organized in runs, each run lasting about one day. Raw data are transferred from the DAQ computers to the permanent storage area at the end of each run. In CUORE about 20 TB/y of raw data are being produced.

A full copy of data is maintained at CNAF and preserved also on tape. The main instance of the CUORE database is located on a computing cluster at the Laboratori Nazionali del Gran Sasso and a replica is synchronized at CNAF. The full analysis framework at CNAF is working and kept up to date to official CUORE software release.

The CUORE data analysis flow consists in two steps. In the first level analysis the event-based quantities are evaluated, while in the second level analysis the energy spectra are produced. The analysis software is organized in sequences. Each sequence consists in a collection of modules that scan the events in the Root files sequentially, evaluate some relevant quantities and store them back in the events. The analysis flow consists in several fundamental steps that can be summarized in pulse amplitude estimation, detector gain correction, energy calibration, search for events in coincidence among multiple bolometers, evaluation of pulse-shape parameters used to select physical events.

The CUORE simulation code is based on the GEANT4 package, for which the 4.9.6 and the 10.xx up to 10.03 releases have been installed. The goal of this work is the evaluation, at the present knowledge of material contaminations, of the background index reachable in the ROI by the experiment. Depending on the specific efficiency of the simulated radioactive sources (sources located outside the lead shielding are really inefficient), the Monte Carlo simulation could exploit from 5 to 500 computing nodes, with durations up to some weeks. Recently Monte Carlo simulations of the CUORE calibration sources were also performed at CNAF. Thanks to these simulations, it was possible to produce calibration sources with an activity specifically optimized for the CUORE needs.

In 2018 the CNAF computing resources were exploited for the production of a preliminary measurement of the 2-neutrino double-beta decay of ^{130}Te. In order to obtain this result, which was based on the 2017 data, both the processing of the expeirimental data and the production of Monte Carlo simulations were required. In the last two months of the year a data reprocessing campaign was performed with an updated version of the CUORE analysis software. This reprocessing campaign, which also included the new data acquired in 2018, allowed to verify the scalability of the CUORE computing model to the amount of data that CUORE will have to process in a few years from now.

References

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[2] Alduino C *et al.* (CUORE) 2018 *Phys. Rev. Lett.* **120** 132501 (*Preprint* `1710.07988`)

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