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Results from CUORICINO and perspectives for CUORE

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We will briefly report on the present results of CUORICINO in view of the perspectives for CUORE, a Cryogenic Undergroud Observatory of Rare Events, recently proposed and approved by the Scientific Committee of the Gran Sasso Underground Laboratory . Even if both setups can be used also for searches on other rare events like interactions of WIMPS and of solar axions or rare nuclear decays the present report will deal only with results and perspectives concerning double beta decay.

1. The principle of thermal detection

As it is well known direct searches on double beta decay (DBD) can be carried out with two techniques: by inserting thin sheets of a DBD active source in layers of detecting material, as in the NEMO experiments [1], or by using the same material as source and detector of the event [2]. The use of thermal detectors in this latter approach has been suggested twenty years ago [3] , but only a series of experiments on DBD of ^{128}Te and on ^{130}Te based on this technique has been carried out so far in the Laboratorio Nazionale del Gran Sasso [4].

The principle of these detectors is shown in Fig 1.

When a diamagnetic and dielectric crystal is kept at low temperature, its heat capacity is proportional to the inverse of the cube of the operating temperature and can therefore become exceedingly small. As a consequence even the tiny energy delivered in this absorber by a charged particle can be revealed by means of a suitable thermal sensor.

Thermal detectors, even if still in their infancy, have reached already excellent energy resolutions: down to a few eV at energies of the ^{55}Mn X-rays, twenty time better than any other detectors, and of a few keV in the MeV region which is relevant for DBD searches. In the case of DBD searches, thermal detectors provide in addition a great advantage: the possibility to investigate in suitable compounds a large choice of DBD active nuclei. This seems to us essential for two distinct reasons: the uncertainty in the evaluation of nuclear matrix elements, and the

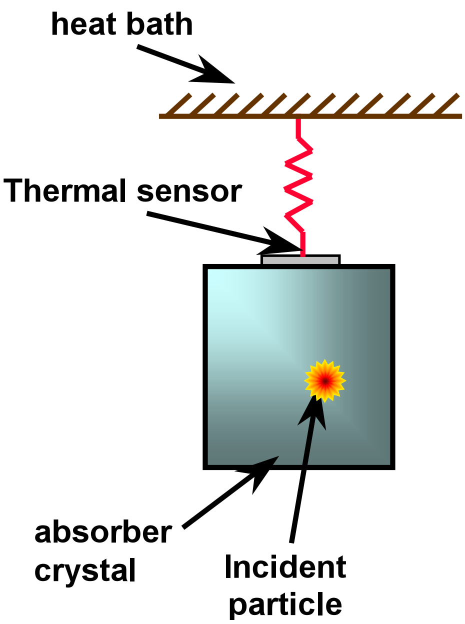

Fig.1

fact that the peak due to neutrinoless DBD could be in principle mimicked by some not yet identified peak due to radioactivity. The discovery of two (or more) peaks at the different energies expected for neutrinoless DBD of different nuclei would be an unambiguous prove of the existence of this process. Our present choice is for natural Te for the following reasons:

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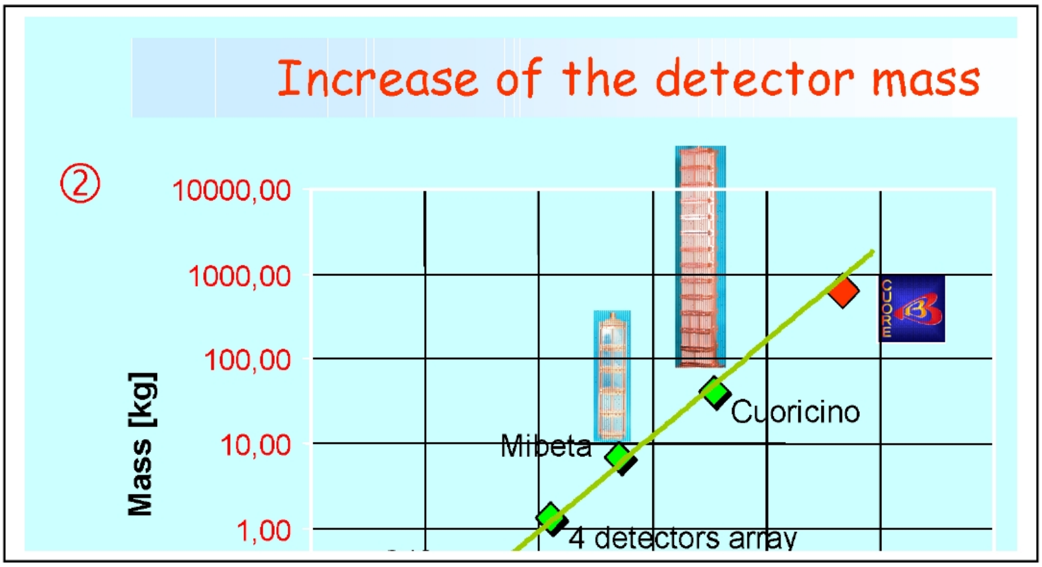


Fig.2

- good isotopic abundance (33.87 %) which make isotopic enrichment unnecessary or very cheap
- large transition energy (2 528.8 keV)
- already proved two neutrino DBD of ^{130}Te [4]

All measurements on DBD of ^{130}Te have been carried out in the Gran Sasso Underground Laboratory with arrays of increasing mass as shown in Fig.2

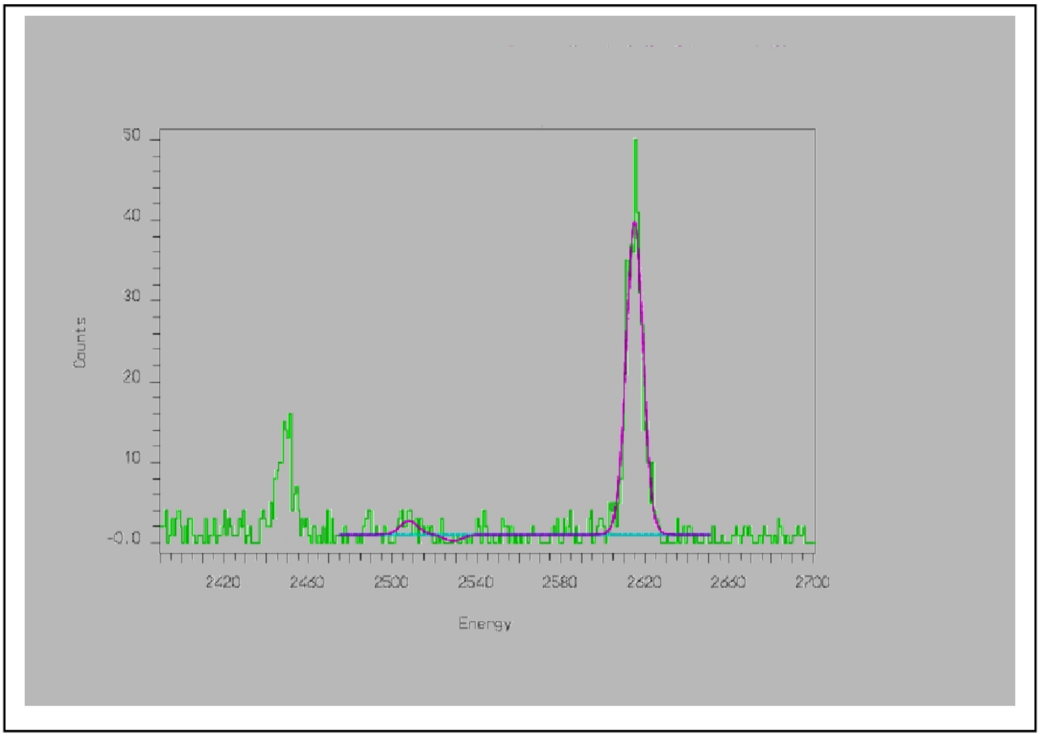


Fig. 3

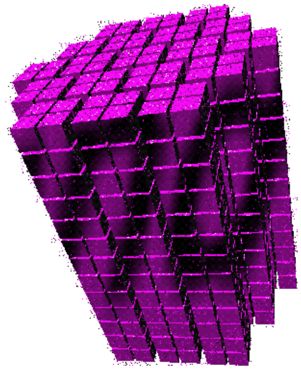
2. CUORICINO

CUORICINO is presently running in Hall A of the Laboratori Nazionali del Gran Sasso to search for DBD of ^{130}Te and other rare events. It is an array of 18 crystals of TeO_2 of 3x3x6 cm^3 + 44 crystals 5x5x5 cm^3 corresponding to 40.7 kg of mass , by far the largest than in any other cryogenic detector.

The active mass of ^{130}Te is 11.1 kg, the larger operating one even if only slightly superior to the one of ^{76}Ge [5]. Presently the background in the region of neutrinoless DBD is .17±.02 c /kev/ kg/ y. After a few months of effective running time the 90% c.l. lower limit for neutrinoless DBD of ^{130}Te is 1 x 10^{24} years (Fig.3) (note the nearby peak at 2505 keV due to ^{60}Co). Taking largely into account the uncertainty in nuclear matrix element , is constraints the effective neutrino mass in the region .26 – 1.4 eV , partially covering the mass interval indicated by H.Klapdor et al [5].

3. CUORE

CUORE will be an array of 988 cubic crystals of 5 cm side grouped in 19 colums with 3 flours of 4 crystals. The total mass will be 750 kg TeO_2 , corresponding to 600 kg and to 203 kg of ^{130}Te. The array will be shielded (from the interior to the exterior) by layers of Roman, low radioactivity and Modern Lead with ^{210}Pb contamination of < 4 mBq/kg, 16 ±4 Bq/kg and ~ 160 Bq/kg, respectively. The sensitivity of CUORE to the effective neutrino mass is obviously dependent on the expected value of the background in the region of neutrinoless DBD [6]. We have considered two options: a conservative value of 0.01 counts keV^{-1} kg^{-1} y^{-1} as expected by extrapolation from the present value of CUORICINO, and 0.001 counts keV^{-1} kg^{-1} y^{-1} as expected by a reasonable improvement in the reduction of the bulk and surface contamination of the crystals and of the surface contamination of the Copper frame.



The corresponding upper limits on $<m_\nu>$ would be (0.024-0.13) and (0.016-0.09) according to a wide choice among the various calculations of nuclear matrix elements. We are also investigating two " active" methods for further reducing the background:

a. placing thin layers of Silicon in thermal contact with the crystals: These layers will also act as thermal detectors producing pulses with totally different time structure with respect to those produced by the main TeO_2 absorbers. Anticoincidence between these pulses will strongly suppress the background from surface.
b. slightly doping the absorbers in order to enable them to scintillate. The genuine DBD events which produce scintillation and heat will be then *discriminated by coincidence* from those coming from α particles or recoils with low scintillation pulses. We would like to note that this coincidence procedure is the opposite of the *anticoincidence* one adopted in thermal Dark matter searchs.

We would like to add in conclusion that , while the present CUORE project is addressed to the search of DBD of ^{130}Te, many other nuclear candidates can be investigated in CUORE exploiting the unique property of thermal detectors which allow the use of a wide variety of double beta active absorbers. A list of possible absorbers is reported in the Table.

All these absorbers have been successfully operated as thermal detectors by the Milan group, with the exception of the Neodymium compounds. The present TeO_2 option looks very attractive due to the large transition energy of ^{130}Te and it large isotopic abundance, which make possible extension by enrichment very cheap. Location of CUORE in Hall C of the Gran Sasso Laboratory is already being designed.

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Compound	**Isotopic abundance**	**Transition energy**	**Scintillation**
^{48}**Ca**F_2	.0187 %	4272 keV	Yes
^{76}**Ge**	7.44 "	2038.7 "	No
^{100}**Mo**PbO_4	9.63 "	3034 "	Yes
^{116}**Cd**WO_4	7.49 "	2804 "	Yes
^{130}**Te**O_2	34 "	2528 "	?
^{150}**Nd**F_3 ^{150}**Nd**GaO_3	5.64 "	3368 "	Yes