First Results of the Cuoricino Experiment

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on behalf of the CUORE collaboration*

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Thermal Detectors

\[ \frac{dR}{dE} \approx 20 \text{k}\Omega/\text{keV} \]

- heat sink \((\sim 9 \text{ mK})\)
- weak thermal coupling \((\sim 4 \text{ pW/mK})\)
- thermometer \((\text{NTD Ge, } R \sim 100 \text{M}\Omega \text{, } I \sim 50 \text{ pA})\)
- crystal absorber \((\text{TeO}_2)\)

incident particle

\(R_{\text{load}}\)

\(R(T)\)

\(R_{\text{load}}\)
Thermal Detectors - Stability

FWHM @2615 = 6 keV

FWHM @2615 = 30 keV

FWHM @~8MeV ~ 90 keV

FWHM @~8MeV ~ 5 keV
Mibeta ($^{130}$Te)

5 modules, 4 detectors each, arranged in a tower-like structure (6.8 kg)

Every detector is a TeO$_2$ crystal 3x3x6 cm$^3$ (340 g)

Cold finger: 7 mK

The tower was surrounded by a Roman lead inner shield
**Mibeta Results**

Total background spectrum of the 20 crystal array around the DDB0ν region

![Graph showing energy spectrum with DBD Q-value highlighted]

Total statistic \( \sim 4.3 \text{ kg x y.} \)

\[ \text{Bkg} \sim 0.3 \text{ c/keV/kg/y} \]

\[ \tau_{1/2}^{0\nu} \geq 2.08 \times 10^{23} \text{ y} \ [90\% \text{ CL}] \]

\[ \langle m_\nu \rangle \leq 1.1 - 2.6 \text{ eV} *[90\% \text{ CL}] \]

The central detectors are almost completely surrounded by active materials.
Substantial improvement in BKG reduction.

11 modules
4 detectors each
Dimension: 5x5x5 cm$^3$
Mass: 790 g

2 modules
9 detectors each,
Dimension: 3x3x6 cm$^3$
Mass: 340 g

Total mass
40.9 kg
Cuoricino Single Module

A Cuoricino module

Ge NTD thermistor
Almost all the operations done in nitrogen atmosphere
Tower assembling

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Overall Layout

MIBETA

CUORICINO

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Cool down: february 2003

Detectors: 14 electrical connection were lost during the cooling of the tower, as a result 14 detectors cannot be read-out (to recover the electrical connections it is necessary to warm up the cryostat)

4x11 = 44 large size crystals (~5x5x5 cm\(^3\) av. mass = 790 g)  
9x2 = 18 small size crystals (~3x3x6 cm\(^3\) av. mass = 330 g)

Active mass during this run:

- 32 working  
- 16 working

\[
\begin{align*}
32 \times 0.790 &= 25.28 \text{ kg} \\
12 \times 0.330 &= 3.96 \text{ kg} \\
2 (^{130}\text{Te-enriched}) \times 0.330 &= 0.495 \text{ kg}^{130}\text{Te} \\
2 (^{128}\text{Te-enriched}) \times 0.330 &= 0.543 \text{ kg}^{128}\text{Te}
\end{align*}
\]

Total active mass: 10.4 kg \(^{130}\text{Te}\)
Detectors performances

Pulse height distribution $\mu$V/MeV
(normalized to 1 kg of TeO$_2$)

- Average pulse height for 5x5x5 crystals = 340 $\mu$V/MeV
- Average pulse height for 3x3x6 crystals = 440 $\mu$V/MeV

FWHM [keV] of the 2615 keV gamma line of $^{208}$Tl (calibration with a $^{232}$Th source ~ 3 days)
- Average 5x5x5 cm$^3$ crystals ~ 7 keV
- Average 3x3x6 cm$^3$ crystals ~ 9 keV

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$^{232}$Th Calibration

Sum spectrum of all the 5x5x5 cm³ detectors

$\Delta E_{FWHM} = 7$ keV @ 2615 keV
Background in the $\gamma$ region

$\gamma$ peaks from $^{60}\text{Co}$, $^{40}\text{K}$ and $^{208}\text{Tl}$ have a higher intensity in CUORICINO.  
But the lateral lead shielding is now 2 cm less.  
We see the 2505 sum line of $^{60}\text{Co}$ $(4 \pm 1.5)$ c/kg/y.
Background in the $\alpha$ region

Uranium $\alpha$ line are reduced

<table>
<thead>
<tr>
<th>Energy Range</th>
<th>MiDBD-II</th>
<th>Cuoricino</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000-2000 c/keV/kg/y</td>
<td>$3.07 \pm .1$</td>
<td>$3.39 \pm .05$</td>
</tr>
<tr>
<td>2000-3000 c/keV/kg/y</td>
<td>$0.533 \pm .004$</td>
<td>$0.38 \pm .02$</td>
</tr>
<tr>
<td>3000-4000 c/keV/kg/y</td>
<td>$0.243 \pm .003$</td>
<td>$0.23 \pm .02$</td>
</tr>
<tr>
<td>4000-5000 c/keV/kg/y</td>
<td>$1.84 \pm .01$</td>
<td>$0.55 \pm .02$</td>
</tr>
</tbody>
</table>
Preliminary result on $^{130}$Te $\beta\beta$–0ν decay

anticoincidence spectrum, only 5x5x5 crystals

0.23 ± 0.04 c/keV/kg/γ

Statistic collected: 2,26 kg × γ

\[ \tau_{1/2}^{0ν} \geq 5 \times 10^{23} \text{y (90\% CL)} \]
Background sources

Extremely low statistics, need to be confirmed also by simulations

BKG in the $\beta\beta_{0}\nu$ seems to be due to $^{208}\text{Tl}$ $\gamma$’s
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2480-2600 keV ($\beta\beta^{130}$Te transition energy = 2528.8 keV)
anticoincidence spectrum, only 5x5x5 crystals

$b = 0.23 \pm 0.04$ c/keV/kg/y

3 year sensitivity CUORICINO (full mass): $b=0.23$ $\Gamma=8$ keV

$F^{0\nu}_{3 years} \approx 1 \times 10^{25}$ y
CUORICINO TO CUORE

CUORICINO proves the feasibility of a large bolometric array with the tower-like structure. Detector performances are not affected by the increase in crystal size (from 340 g to 790 g).

Array of 1000 detectors:
- 25 towers
- 10 modules/tower
- 4 detectors/module

\[ M = 0.75 \text{ ton} \]
A completely new set-up will allow the optimization of shielding.

CUORE is specifically designed to reduce as far as possible the amount of materials interposed between the crystals.

The high granularity of the CUORE detector will allow to use with high efficiency the coincidence/anticoincidence technique to identify and reject background events.

**Contribution to the ββν region from bulk contaminations**

- TeO$_2$: $4.1 \times 10^4$ c/keV/y/kg
- Copper: $2.7 \times 10^4$ c/keV/y/kg
- Lead: $3.5 \times 10^4$ c/keV/y/kg

$1 \times 10^3$ c/keV/Y/kg

$4.4 \times 10^4$ c/keV/y/kg

$10^4$ c/keV/y/kg

$45 \times 10^4$ c/keV/y/kg

$6 \times 10^3$ c/keV/Y/kg

The main task is the reduction of *surface radioactivity*.

To reach the background goal we need to improve by a factor $\approx 200$.

From geometry we can gain a factor $5 \div 10$.

$\Rightarrow$ we need to reduce surface radioactivity “only” by a factor $20 \div 40$.
Conclusions

- CUORICINO gave the first encouraging results
- It also demonstrated the feasibility of a larger Experiment
- We plan to recover in October all the detectors
- We will start within this year the R&D on CUORE detectors