News from CUORE-0 (the first tower of CUORE)

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CUORE: Cryogenic Underground Observatory for Rare Events

Array of 988 detectors. 19 CUORICINO-like towers $M = 0.741$ ton of $\text{TeO}_2$ (~200 kg $^{130}\text{Te}$) to measure $0\nu$-DBD of $^{130}\text{Te}$ with bolometric detector.

Sensitivity (5 y): $T_{1/2} = 1.6 \times 10^{26} \, \text{y}$

$m_{\beta\beta} = 41-95 \, \text{meV}$

The CUORE collaboration

New Spokesperson
The CUORE collaboration

Emeritus Spokesperson

New Spokesperson
LNGS underground facility

- Average depth ~ 3650 m.w.e.
- Factor $10^6$ reduction in muon flux to $\sim 3 \times 10^{-8} \mu/(s \cdot cm^2)$
The CUORE $\text{TeO}_2$ bolometers

- Heat sink (8-10 mK)
- Cu holder
- PTFE supports (G)
- TeO$_2$ crystal
- NTD Ge sensor
- Absorber Crystal (C)
- Thermometer
- Incident radiation (E)

$\Delta T = \frac{E}{C}$

$\tau = \frac{C}{G}$
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\( T \sim 1 \text{ s} \)
The CUORE TeO$_2$ bolometers

Pros:
- good energy resolution
- different sources could be investigated
- high efficiency (internal sources)

Cons:
- no dead layer
- low temperature tech required
- slow pulses

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$T = \frac{C}{G}$
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PTFE supports (G)

TeO$_2$ crystal

NTD Ge sensor

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These advantages could be crucial in view of future experiments that aim to investigate all the inverted hierarchy region.

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$\tau = \frac{C}{G}$

$T \sim 1 \text{ s}$
Bolometric 0νDBD experiment evolution

$\Delta E = 6.2 \pm 2.5 \text{ keV} \ (\sim 0.3\% \text{ FWHM})$

Bkg = 0.169±0.006 c/keV/kg/y

$T_{1/2}^{0\nu}(y) > 2.8 \times 10^{24} \text{ y} \ (90\% \ CL)$

CUORICINO
40 kg
(2003-2008)

CUORE
1 ton
(~2014)

Astroparticle Physics 34 (2011)

$\langle M_{bb}\rangle < 0.3 - 0.7 \text{ eV}$

NME from F.Simkovic et al. Phys.Rev. C77
Bolometric $0
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Bkg = $0.169 \pm 0.006 \text{ c/keV/kg/y}$

$T_{1/2}^{0\nu}(\gamma) > 2.8 \times 10^{24} \text{ y} \ (90\% \ CL)$

\[ \langle M_{bb} \rangle < 0.3 - 0.7 \text{ eV} \]

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40 kg
(2003-2008)

\[ \text{CUORE-0} \]
(2012)

\[ \text{CUORE} \]
1 ton
(\sim 2014)

NME from F. Simkovic et al. Phys. Rev. C77
- J. Suhanen et al. Int. J. Mod. Phys. E17
CUORICINO lesson: background origin

Sensitivity of current generation bolometric DBD experiment is limited by bkg.

MC: the background in CUORICINO is due to degraded alpha particles which release only part of their energy in the detector (surface contamination)

\[ \gamma + \gamma \]
\[ ^{60}\text{Co} \]
\[ Q_{0V\beta\beta} \]
\[ (2527\text{keV}) \]

Bkg @ 0vDBD region = 0.161 +/- 0.006 c/keV/kg/y
(ainticoincidence spectrum, 5x5x5 cm\(^3\) crystals)

\[ 30 \pm 10 \% \ ^{232}\text{Th} \ \text{in cryostat (}\gamma\text{)} \]
\[ 10 \pm 5 \% \ \text{TeO}_2 \ \text{surface (}\alpha\text{)} \]
\[ 50 \pm 20 \% \ \text{Cu surface (}\alpha\text{)} \]

C.Arnaboldi et al. Phys.
# CUORE background budget

<table>
<thead>
<tr>
<th>Source</th>
<th>CUORE in the ROI $c/(\text{keV kg } \gamma)$</th>
<th>Source of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmogenic activation of crystals (bulk)</td>
<td>~ 1 $10^{-3}$</td>
<td>NAA + MC</td>
</tr>
<tr>
<td>Gold wires ($^{232}\text{Th}$ and $^{238}\text{U}$) (bulk)</td>
<td>&lt; 1 $10^{-3}$</td>
<td>Bolometric test + HPGe</td>
</tr>
<tr>
<td>Copper frames ($^{232}\text{Th}$) (bulk)</td>
<td>&lt; 1.5 $10^{-3}$</td>
<td>HPGe + NAA + MC</td>
</tr>
<tr>
<td>$^{232}\text{Th}$ in the Roman lead shield (bulk)</td>
<td>&lt; 4 $10^{-3}$</td>
<td>Bolometric + HPGe</td>
</tr>
<tr>
<td>Muon interactions (bulk)</td>
<td>~ 1.8 $10^{-3}$</td>
<td>Measured fluxes + MC</td>
</tr>
<tr>
<td>$\text{TeO}_2$ crystals surface activity</td>
<td>&lt; 4 $10^{-3}$</td>
<td>Bolometric tests (CCVR) + MC</td>
</tr>
<tr>
<td>Surface activity of the mounting structure</td>
<td>&lt; 2-3 $10^{-2}$</td>
<td>Test on small tower + MC</td>
</tr>
<tr>
<td></td>
<td>&lt; 6 $10^{-2}$</td>
<td>Test on small tower + MC</td>
</tr>
</tbody>
</table>

If contamination in the R&D run are due to surface contamination of copper structure

If contamination in the R&D run are due to $^{210}\text{Pb}$ contamination of PTFE (unlikely)

Pessimistic hp: we assumed that all the flat bgk contribution observed in the R&D tests is coming from source that will not improve with the geometry of CUORE.

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F. Alessandria et al. [CUORE coll.] http://arxiv.org/abs/1109.4757v1
F. Alessandria et al. [CUORE coll.] http://arxiv.org/abs/1109.0494v1
CUORE-0: motivation

Critical points in the way of CUORE experiment: uniformity of the detector array and the control of possible recontamination during the detector construction

CUORE-0:
• first tower from the CUORE assembly line
• operated as a stand alone experiment in the CUORICINO cryostat

**CUORE-0 goals:**
- full test and debug of the new CUORE assembly line
  • high statistics check of the improved uniformity of bolometric response
  • identify which operations are critical for the success of CUORE
  • reveal flaws and inefficiencies in the assembly procedures
- permit a thorough exercise of the analysis framework
CUORE-0 detector construction
CUORE-0: sensor-to-crystal connection

The sensor-to-crystal connection (glue spots) drives the detector performance. We have strong indications that this was the largest source of irreproducibility → new semi-automatic system: fast, operator independent, highly-reproducible, minimize radioactive contamination.
CUORE-0: sensor-to-crystal connection
CUORE-0: tower assembly

The assembly of the CUORE-0/CUORE towers must follow very strict prescriptions, because of the extraordinary level of radio-purity required.

- assembly realized inside nitrogen fluxed glove boxes (recontamination-free)
- strict control on all materials and tools touching the tower elements
- simple, fast, reproducible protocols
CUORE-0: tower assembly
CUORE-0: wiring connection

- The 3 steps of the bonding
  1. Gold balls on the Cu pads
  2. Wires bonding
  3. Reinforcing the bonding
CUORE-0: shield installation and transportation to the CUORE-0 hut
CUORE-0: installation…

CUORE-0 assembly already gave us the opportunity to test and fix the procedures and the systems to realize the CUORE detector.

A complete CUORE tower can be assembled in less than 4 weeks

The cool-down of CUORE-0 started in July 2012
CUORE-0: status

CUORE-0 is in the optimization phase
In August 2012 the detector reached base T of about 8 mK
All the active channels survived the cool-down
CUORE collaboration is not ready to release information on resolution and detector performances but these will come very soon
Background: 0.05-0.11 c/keV/kg/y range

If 0.05 c/(keV kg y), expected 2-year sensitivity is

\[ T_{1/2} = 5.9 \times 10^{24} \text{ y @ 90\%CL} \]

(CUORICINO: \( T^{0\nu} > 2.8 \times 10^{24} \text{ y} \))

\[ m_{\beta\beta} = 170-390 \text{ meV} \]

Significance level at which CUORE-0 can observe a DBD signal consistent with the claim in \(^{76}\text{Ge} \) (KK-HK), assuming 0.05 c/keV/kg/y background

- The inner band corresponds to the best-fit value of the claim; the range arises from the “1\(\sigma\)” range of QRPA NME calculations in A. Faessler et al., Phys. Rev. D79 (2009) 053001
- The outer band also includes the 1\(\sigma\) error on the \(^{76}\text{Ge} \) claim

Limited by bkg from cryostat contamination

F. Alessandria et al. [CUORE coll.]

http://arxiv.org/abs/1109.0494v1
CUORE status

- Crystals, almost all arrived (all at LNGS by the end of 2012)
- Copper parts are being machined and cleaned
- Dilution unit delivered to LNGS
- CUORE Hut, and most of all the infrastructures, ready
- Detector assembly line, ready (small modifications)
- Radon abatement system installed
- 3 (of 6) cryostat vessels delivered at LNGS
- Commissioning of the cryostat already started (ends in 2013)

Crystals 12/12
Thermistors 13/03
Cleaned Cu parts 13/12
Cryogenic 13/12
Tower Assembly 14/04
Detector insertion 14/07
Cool Down 14/11

P. Gorla
CUORE status 2012

Parts Storage Area  Dilution Unit  4K shield

Installation of the 300K, 40K, and 4K plates of the CUORE cryostat @ LNGS
Background goal of 0.01 c/keV/kg/y

\[ T_{1/2} = 1.6 \times 10^{26} \text{ y} \]

\[ m_{\beta\beta} = 41-95 \text{ meV} \]

Cuoricino result and CUORE 1\sigma sensitivity overlaid on plots that show the bands preferred by neutrino oscillation data (inner region: best-fit data; outer region: at 3\sigma). Both normal (red) and inverted (green) hierarchies are shown.
Conclusion

• We developed new systems to realize the CUORE detector with the needed radio-purity level
• The new assembly systems and procedures have been tested in the CUORE-0 detector.
• The CUORE-0 prototype has been installed and operated in the CUORICINO cryostat, and will start to give us answers very soon
• The CUORE cryostat commissioning will continue in 2012 and 2013
• Bkg study is completed. Cu surface treatment is the crucial issue
• CUORE data taking in 2014!