Background Evaluation for the CUORE-0 Experiment

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On behalf of the CUORE collaboration

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Cryogenic Underground Observatory for Rare Events

Construction nearing completion @LNGS (Gran Sasso, Italy)

Search for the 0νββ decay of $^{130}$Te

988 TeO$_2$ bolometers, 5x5x5 cm$^3$, arranged in 19 towers (206 kg $^{130}$Te)
CUORE structure

- External lead shield (γ shielding)
- Borated polyethylene (neutron shielding)
- Sequence of copper containers with progressively lower T
- Internal, ancient Roman lead shield (γ shielding, ultra-clean)
- Inner “CuBox” @ 10mK, containing the 19 CUORE towers
CUORE goal

Expected signature from $^{130}$Te $0\nu\beta\beta$: line at the decay Q value - 2527.5 keV

Projected sensitivity @90% C.L: $T_{1/2}^{0\nu} = 9.5 \times 10^{25}$ y

In order to obtain it:

5 keV FWHM

0.01 counts/keV/kg/y background
CUORICINO was an array of 62 TeO$_2$ bolometers that operated from 2003 to 2008 @LNGS

Set a lower bound on $^{130}$Te 0v half life:

$$T^{0v}_{1/2} > 2.8 \times 10^{24} \text{ y}$$
Background in the ROI:

- 40±10% from $^{208}$Tl @ 2615 keV ($^{232}$Th in cryostat)
- 50±20% from materials facing the detector (copper)
- 10±5% from crystal surface
CUORE-0 is the first tower built using the CUORE tower assembly line

52 TeO$_2$ bolometers (11 kg $^{130}$Te)
in the old CUORICINO cryostat

A lot of work has gone into background reduction to achieve the CUORE goal (0.01 counts/keV/kg/y in ROI)

Data taking started in 2013, will stop in 2015

Goals:
- Proof of concept for CUORE
- Test of the CUORE assembly line
- Test of the DAQ/analysis framework
- Background model for CUORE

It has already reached 5 keV resolution @ 2615keV
Background reduction strategy for CUORE and CUORE-0:

- Material screening to minimize bulk contaminations (Copper, Lead..)
- TeO$_2$ bulk contaminations: clean production, minimized cosmogenic activation (shipped by boat, stored underground)
- TeO$_2$ surface contaminations: crystal polishing
- Copper facing detector: TECM cleaning (sequence of mechanical, chemical, electro-chemical and magneto-plasma treatments)
- Improved tower structure: less copper facing the detectors
CUORE-0 vs. CUORICINO

Blinding procedure: random number of events swapped between ROI and $^{208}\text{Tl} \, @ \, 2615 \, \text{keV}$
CUORE-0 vs. CUORICINO

Reduction by a factor \(\sim 2.5\) in ROI

CUORE-0 Preliminary
Total Exposure: 25.8 kg y
Reduction by a factor $\sim 6$ in the $\alpha$ flat background
CUORE-0 vs. CUORICINO

CUORE-0 Preliminary Total Exposure: 25.8 kg y

Event rate [counts/keV/kg/y]

2600 2800 3000 3200 3400 3600 3800
Energy [keV]

CUORE-0

Cuoricino

<table>
<thead>
<tr>
<th></th>
<th>0νββ region (cnts/(keV kg y))</th>
<th>2700-3900 keV (cnts/(keV kg y))</th>
<th>ε(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuoricino</td>
<td>0.153 ± 0.006</td>
<td>0.110 ± 0.001</td>
<td>83</td>
</tr>
<tr>
<td>CUORE-0</td>
<td>0.063 ± 0.006</td>
<td>0.020 ± 0.001</td>
<td>78</td>
</tr>
</tbody>
</table>
CUORE-0 Preliminary Total Exposure: 25.8 kg y

208Tl line @ 2615 keV
Same rate, 232Th contamination comes from the cryostat (same as CUORICINO)
CUORE-0 Preliminary
Total Exposure: 25.8 kg y

Event rate [counts/keV/kg y]

CUORE-0
Cuoricino

$^{190}$Pt line @ 3249 keV
Crystal growth in Pt crucible; $^{190}$Pt naturally present
1. $e^+e^-$ annihilation
2. $^{214}$Bi ($^{238}$U chain)
3. $^{40}$K
4. $^{208}$Tl ($^{232}$Th chain)
5. $^{60}$Co
6. $^{228}$Ac ($^{232}$Th chain)

Gamma line analysis: identify source isotopes
CUORE-0: Background

1. $e^+e^-$ annihilation
2. $^{214}$Bi ($^{238}$U chain)
3. $^{40}$K
4. $^{208}$Tl ($^{232}$Th chain)
5. $^{60}$Co
6. $^{228}$Ac ($^{232}$Th chain)

Continuum analysis + ratios: identify source position

Calibration ($^{232}$Th): example of external source (outer cryostat shielding)

$^{232}$Th source in the outer shielding
Event multiplicity + tail shape: surface contamination depth and location
(α particles)

CUORE-0 Preliminary
Total Exposure: 25.8 kg y

- M2: Crystal surface
- M1, only α line: Copper (near) surface
- M1, only Q value line: Crystal bulk
All data is used in MC simulations to estimate contributions to CUORE
Summary

- CUORE-0 shows a substantial background reduction with respect to CUORICINO, thanks to improved material selection and cleaning
  - Factor 2.5 in the ROI
  - Factor 6 in the alpha region
- The 5 keV FWHM goal has already been reached by CUORE-0
- Background analysis and extrapolation to CUORE show that the background goal (0.01 counts/keV/kg/y) is within reach

Thanks for your attention