The Electron Capture in $^{163}$Ho experiment

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on behalf of the ECHo Collaboration

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\[
\frac{A}{Z} X + e^- \rightarrow \frac{A}{Z-1} Y^* + \nu
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The excited atomic shell of daughter nucleus deexcites via X-rays, Auger electrons and/or Coster–Kronig transitions.
$^{A}_{Z}X + e^- \rightarrow ^{A}_{Z-1}Y^* + \nu$

The excited atomic shell of daughter nucleus deexcites via X-rays, Auger electrons and/or Coster–Kronig transitions. The energy release can be measured calorimetrically.

\[
\frac{dN}{dE} = A (Q_{EC} - E)^2 \sqrt{1 - \frac{m_{\nu}^2}{(Q_{EC} - E)^2}} \sum_H B_H \phi_H^2(0) \frac{\Gamma_H}{2\pi} \frac{\Gamma_H^2}{(E - E_H)^2 + \Gamma_H^2}
\]
$^{163}\text{Ho} + e^- (M, N, O) \rightarrow ^{163}\text{Dy}^* + \nu$

Halflife of $\tau_{1/2} = 4570$ a, lowest known $Q_{\text{EC}}$ of 2.555(16) keV
$^{163}_{63} Ho + e^- (M, N, O) \rightarrow ^{163}_{62} Dy^* + \nu$

Halflife of $\tau_{1/2} = 4570$ a, lowest known $Q_{EC}$ of 2.555(16) keV

Large count rate in the endpoint region.
Measurements of the Spectrum


(a) F. Gatti et al., Physics Letters B 398 (1997) 415-419
Measurements of the Spectrum


1997
Cryogenic detector

1984
Si(Li) detector

1992
Proportional Counter

(a) F. Gatti et al., Physics Letters B 398 (1997) 415-419

Example:

Metallic Magnetic Calorimeter

\[ \Delta T = \frac{\Delta E}{C} \]

\[ \Delta \Phi \propto \frac{\partial M}{\partial T} \Delta T \]
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fast coupling phonon–spin

Direct SQUID readout of the change in magnetic flux
<table>
<thead>
<tr>
<th>Experiment</th>
<th>Material/Device</th>
<th>Irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au:Er</td>
<td>Metallic magnetic microcalorimeters (MMC)</td>
<td>n irradiation Er(n,γ)</td>
</tr>
<tr>
<td>MoCu or MoAu Transition edge sensors (TES)</td>
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Au:Er
Metallic magnetic microcalorimeters (MMC)

n irradiation
Er(n,γ)

funding for ECHO-1k demonstrator
granted by DFG

MoCu or MoAu
Transition edge sensors (TES)

n irradiation
Er(n,γ)

funding approved

MoCu
Transition edge sensors (TES)

proton irradiation
Dy(p,xn)
ECHO

163Ho Experiments


Au:Er
Metallic magnetic microcalorimeters (MMC)
n irradiation Er(n,γ)

MoCu or MoAu
Transition edge sensors (TES)
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MoCu
Transition edge sensors (TES)

n irradiation Er(n,γ)

proton irradiation Dy(p,xn)

Common Goal: Measure mν with sub eV sensitivity

ECHO-1k demonstrator
funding approved

NuMECS
Goal of ECHo–1k:

- Total activity of 1kBq for $10^{11}$ events $^{163}\text{Ho}$.  
- Sensitivity < 10 eV for $m_{\nu}$.  
- Scalability for $A = 1\text{MBq}$ and 1eV sensitivity.
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Parameters:

2 chips x64 pixels x 10 Bq $^{163}$Ho
dedicated cryostat

MMCs with $\Delta E = 2$ eV

$\tau_r = 0.1 \mu s$
Rise Time $\tau_r \sim 130$ ns

$\Delta E_{\text{FWHM}} = 4.7\text{ eV} \ @ 6\text{ keV}$

Non-Linearity $< 1\% \ @ 6\text{keV}$

Presently most precise $^{163}\text{Ho}$ spectrum

New implanted detector free of $^{144}\text{Pm}$ is currently operated

<table>
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<tr>
<th></th>
<th>$E_h$ lit.</th>
<th>$E_h$ exp.</th>
<th>$\Gamma_h$ lit.</th>
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<tbody>
<tr>
<td>MI</td>
<td>2.047</td>
<td>2.040</td>
<td>13.2</td>
<td>13.7</td>
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<tr>
<td>MII</td>
<td>1.845</td>
<td>1.836</td>
<td>6.0</td>
<td>7.2</td>
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<tr>
<td>NI</td>
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<td>0.411</td>
<td>5.4</td>
<td>5.3</td>
</tr>
<tr>
<td>NII</td>
<td>0.340</td>
<td>0.333</td>
<td>5.3</td>
<td>8.0</td>
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<tr>
<td>OI</td>
<td>0.050</td>
<td>0.048</td>
<td>5.0</td>
<td>4.3</td>
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The reliable extraction of $^{163}$Ho ions from small samples ($10^{-15}$ atoms) has been shown with TRIGATRAP. A value of $Q_{EC} = 2.5(7)$ keV has been measured.

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The ion source combined with the PI-ICR technique is going to be used in SHIPTRAP next year, the sensitivity is expected to be increased by more an order of magnitude.
In 3 years, expect $^{163}\text{Ho}$ spectrum with $10^{11}$ counts giving a sensitivity of $m_\nu \approx 10$ eV.

The ECHo–1k demonstrator phase is funded since March 2015.

A new detector has been loaded with clean $^{163}\text{Ho}$.

The detector is currently operated.

No traces of $^{166m}\text{Ho}$ have been detected so far.

The ion source for SHIPTRAP has been tested.