

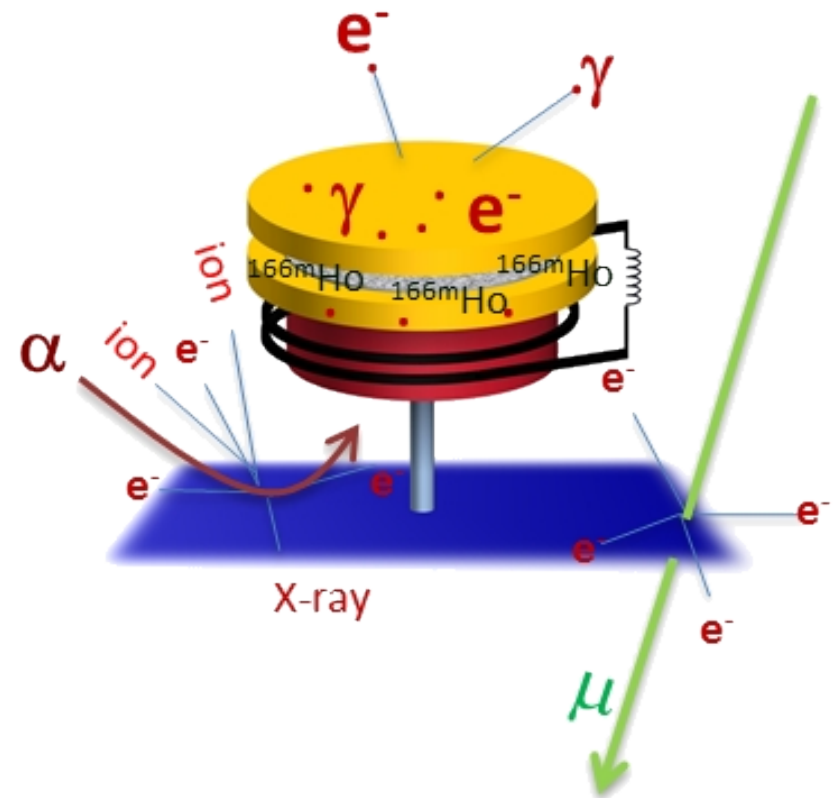


Background Analysis and Reduction for the ECHO Experiment

Stephan Scholl
on behalf of the
ECHO Collaboration

Kepler Center for Astro and Particle Physics,
Eberhard–Karls–Universität Tübingen

TAUP 2015, Torino, September, 9th 2015

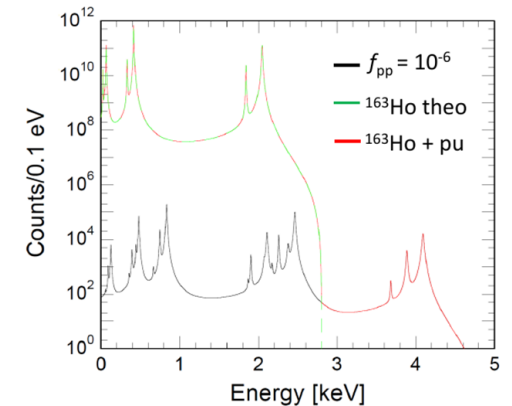


Several sources of background have to be reduced to achieve the optimal sensitivity for the ECHO experiment.

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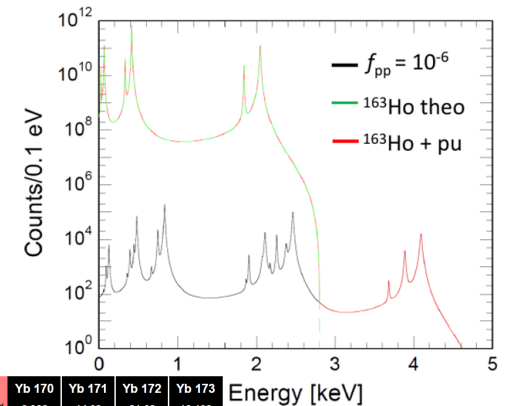
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Depends on the activity of ^{163}Ho .



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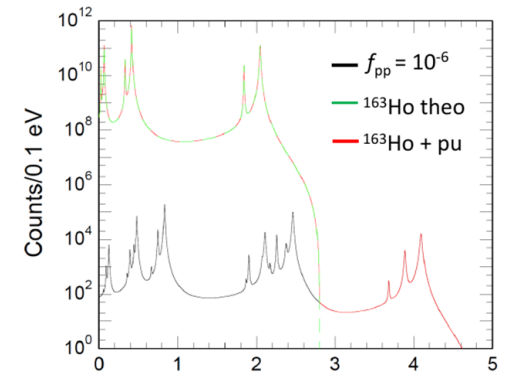


Yb					Yb 168 0.123 0.240	Yb 169 46 s 0.240	Yb 170 2.982 0.12	Yb 171 14.09 0.60	Yb 172 21.68 0.13	Yb 173 16.103 0.16	
Tm						Tm 167 9.25 d 0.19	Tm 168 93.1 d 0.108	Tm 169 100 0.108	Tm 170 127.8 d 0.108	Tm 171 1.92 a 0.108	Tm 172 63.6 h 0.108
Er	Er 162 0.139 0.19	Er 163 75 m 0.13	Er 164 1.601 0.13	Er 165 10.3 h 0.17	Er 166 33.503 0.680	Er 167 22.989 0.680	Er 168 28.978 0.680	Er 169 9.40 d 0.680	Er 170 14.910 0.680	Er 171 7.52 h 0.680	
Ho			Ho 163 1.1 s 0.170	Ho 164 4670 a 0.170	Ho 165 100 0.170	Ho 166 1200 a 0.170	Ho 167 3.1 h 0.170				
Dy	Dy 160 2.329 0.60	Dy 161 18.889 0.60	Dy 162 25.475 0.170	Dy 163 24.896 0.170	Dy 164 28.280 0.170	Dy 165 1.3 m 0.170	Dy 166 81.5 h 0.170				

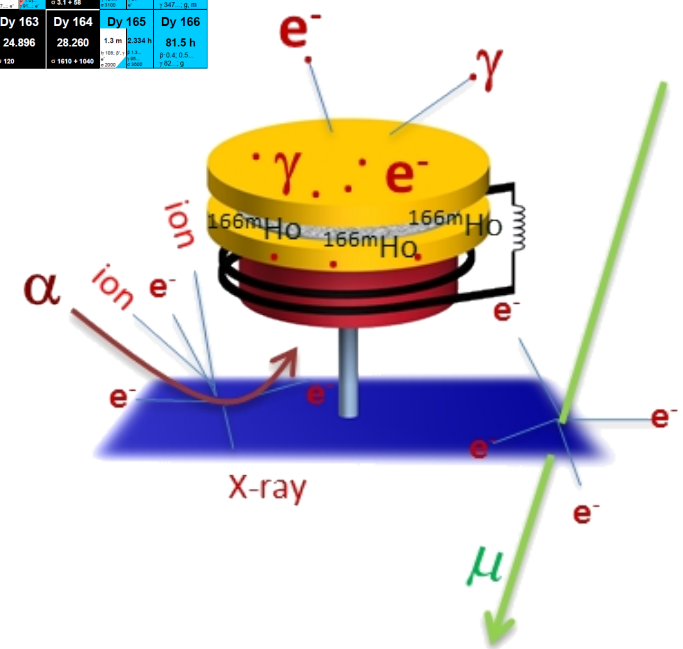
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- Irreducible background due to pile-up. Depends on the activity of ¹⁶³Ho.
- Bulk contaminations of the detectors. Depends on coimplanted isotopes.
- Ambient Radioactivity Dangerous due to the secondary radiation, i.e. fluorescence, PIXE and Auger electrons.
- Muons Secondary particles in the wake of the cosmogenic particle.



Yb 168	Yb 169	Yb 170	Yb 171	Yb 172	Yb 173
0.123	46 s	32.0 d	2.982	14.09	21.68
0.240	0.240	0.12	0.63	0.15	0.16
Tm 167	Tm 168	Tm 169	Tm 170	Tm 171	Tm 172
9.25 d	93.1 d	100	127.8 d	1.92 a	63.6 h
0.19	0.13	0.17	0.60	0.23	0.31
Er 162	Er 163	Er 164	Er 165	Er 166	Er 167
0.139	75 m	1.601	10.3 h	33.503	22.989
0.19	0.13	0.17	0.60	0.23	0.31
Ho 163	Ho 164	Ho 165	Ho 166	Ho 167	
1.1 s	4670 a	37 m	100	3.1 h	
0.19	0.13	0.17	0.60	0.23	0.31
Dy 160	Dy 161	Dy 162	Dy 163	Dy 164	Dy 165
2.329	18.889	25.475	24.896	28.280	81.5 h
0.60	0.60	0.170	0.130	0.1610 + 1040	0.150 + 9

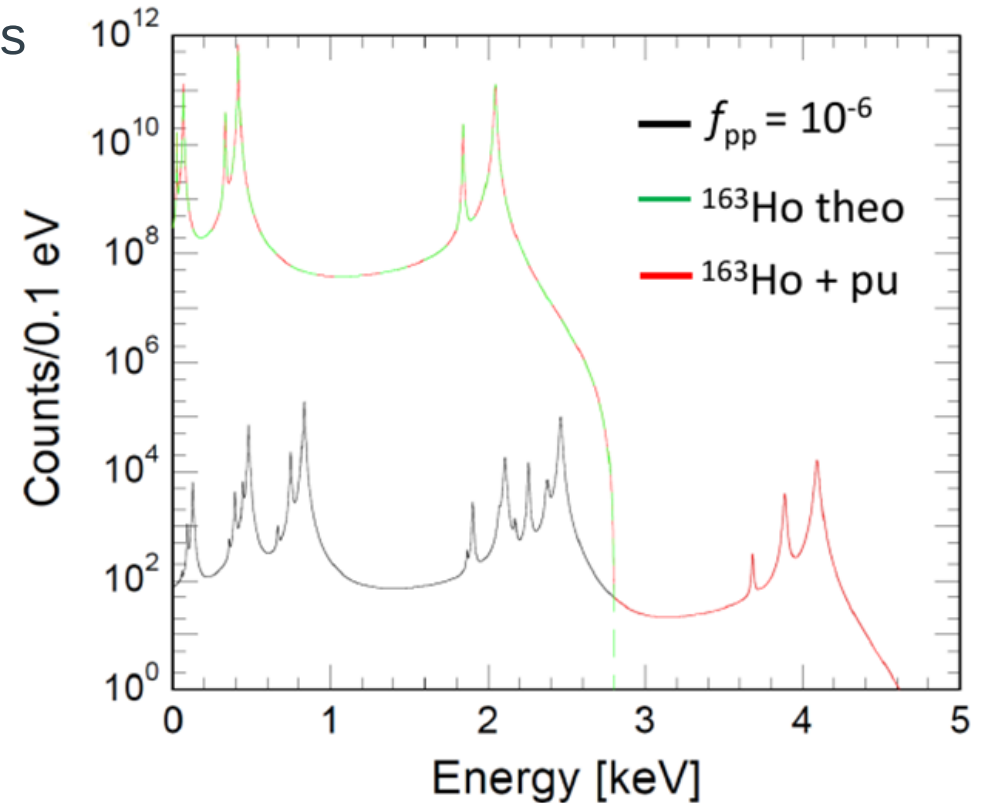


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A irreducible background for experiments of the ECHO type is given by pile up of the investigated decays.

The total background due to the pile-up rate for a given Q-value is:

$$\begin{aligned}
 B &= f_{pp} A N t \\
 &= A^2 \tau_r c(Q) N t
 \end{aligned}$$

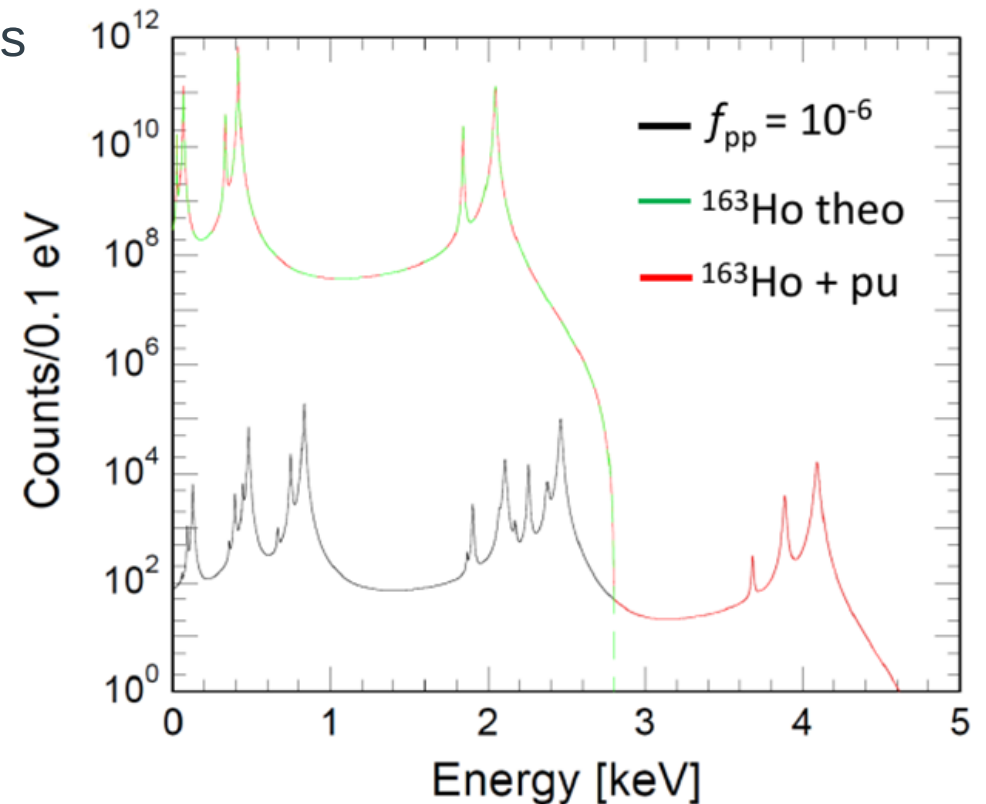


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For 10^{10} events, the pile-up background is about $3 \cdot 10^{-5}$ to $3 \cdot 10^{-4}$ counts per eV and detector and day in the region around Q_{EC} of 2.8 keV.

The background due to pile-up sets the level to which other background have to be reduced at least.

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^{166m}Ho is the most dangerous internal background which is coimplanted with ^{163}Ho .

Yb 70					Yb 168 0.123 <small>σ 2400</small>	Yb 169 46 s 32.0 d <small>h(24k), e(103, 168), g(3900)</small>	Yb 170 2.982 <small>σ 12</small>	Yb 171 14.09 <small>σ 53</small>	Yb 172 21.68 <small>σ -1.3</small>	Yb 173 16.103 <small>σ 16</small>
Tm 69					Tm 167 9.25 d <small>ε; γ 532...; m</small>	Tm 168 93.1 d <small>ε; β⁺...; β⁻...; γ 198...; e</small>	Tm 169 100 <small>σ 108</small>	Tm 170 127.8 d <small>β⁻ 1.0...; ε 84...; e; σ 92</small>	Tm 171 1.92 a <small>β⁻ 0.1...; γ(67) σ; σ -160</small>	Tm 172 63.6 h <small>β⁻ 1.8...; γ 79, 1094...</small>
Er 68	Er 162 0.139 <small>σ 19</small>	Er 163 75 m <small>ε; β⁺...; γ(1114); g</small>	Er 164 1.601 <small>σ 13</small>	Er 165 10.3 h <small>ε; no γ</small>	Er 166 33.503 <small>σ 17</small>	Er 167 22.869 <small>σ 650</small>	Er 168 26.978 <small>σ 2.3</small>	Er 169 9.40 d <small>β⁻ 0.3...; γ(110...); e</small>	Er 170 14.910 <small>σ 8</small>	Er 171 7.52 h <small>β⁻ 1.1...; γ 308...; σ 370</small>
Ho 67			Ho 163 1.1 s <small>γ 208</small>	Ho 164 4570 a 37 m 29 m <small>ε; β⁺ 1.0...; γ 91...; e</small>	Ho 165 100 <small>σ 3.1 + 58</small>	Ho 166 1200 a 26.80 h <small>β⁻ 0.07...; γ 184...; e; σ 3100</small>	Ho 167 3.1 h <small>β⁻ 1.9...; γ 347...; g, m</small>			
Dy 66	Dy 160 2.329 <small>σ 60</small>	Dy 161 18.889 <small>σ 600</small>	Dy 162 25.475 <small>σ 170</small>	Dy 163 24.896 <small>σ 120</small>	Dy 164 28.260 <small>σ 1610 + 1040</small>	Dy 165 1.3 m 2.334 h <small>γ 108; β⁻ 1.3...; e; σ 2000; σ 3800</small>	Dy 166 81.5 h <small>β⁻ 0.4; 0.5...; γ 82...; g</small>			

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- β -emitter ($Q=1854.7$ keV) with a long life time of 1200a.
- Low E β -decay modes with $E_{\text{Mean}} = 8.38$ keV(17.2%) and 19.02 keV (73.9%).
Some deexcitation γ s can escape our detector (5 μm of Au).

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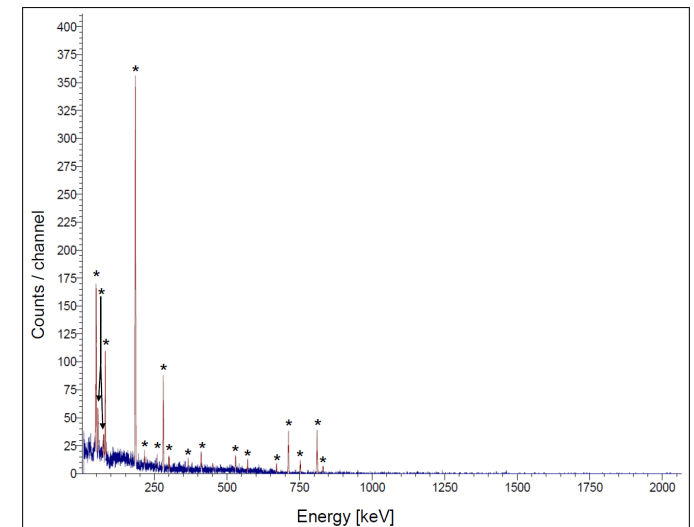
^{166m}Ho is coproduced when Er is irradiated with neutrons.

The amount of ^{166m}Ho within the ^{163}Ho sample has to be controlled and reduced if possible.

Measure the waste material from the implantation process.

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The ratio R of $^{166\text{m}}\text{Ho}/^{163}\text{Ho}$ has to be measured.
After neutron irradiation, R is about 10^{-5} .

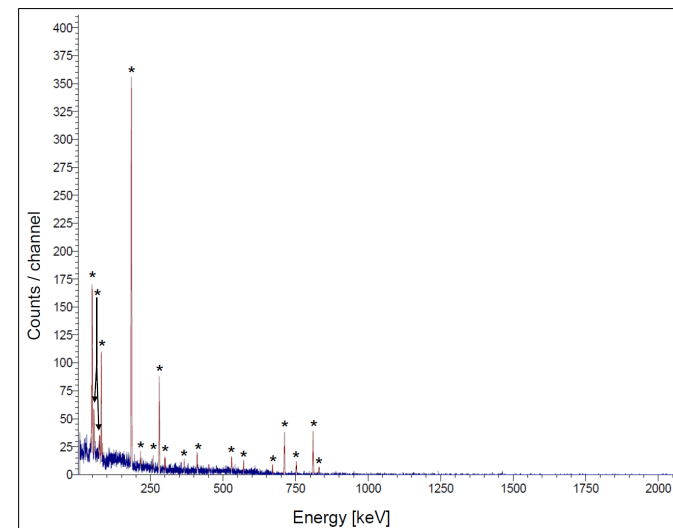


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The exact value of R of the material implanted
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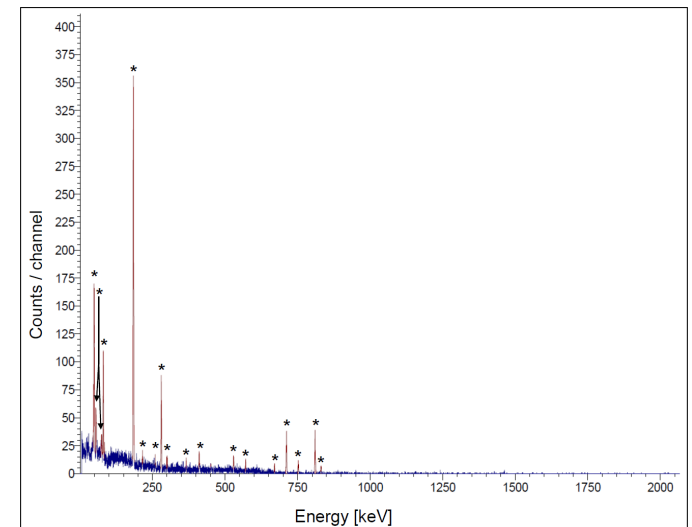
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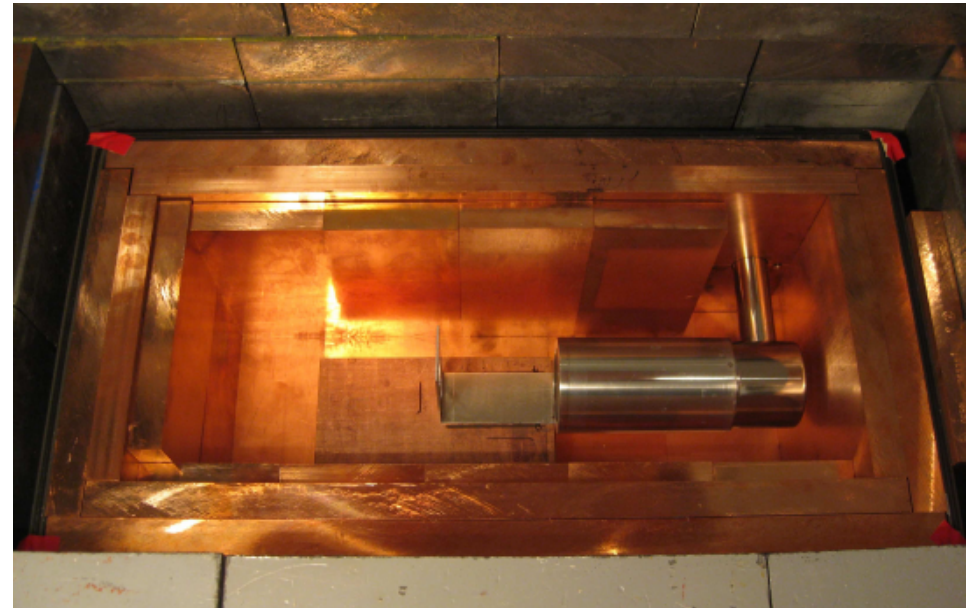
Two measurements are required:

- HP Ge measurement of the γ -spectrum to determine the activity of $^{166\text{m}}\text{Ho}$ in the sample.
- Neutron activation analysis to determine the ^{163}Ho activity in the sample.



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Screening measurements at Tuebingen UGL and Dresden Felsenkeller have been conducted with a HP-Ge detector.



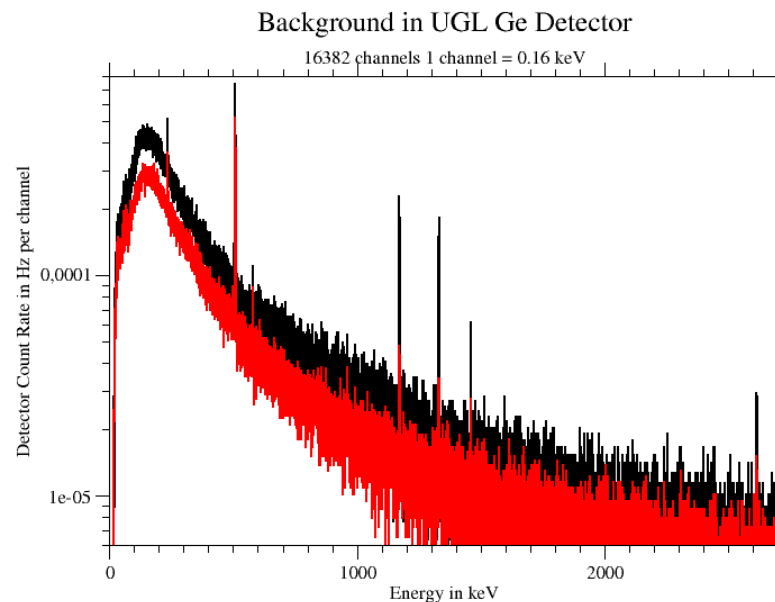
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Screening measurements at Tuebingen UGL and Dresden Felsenkeller have been conducted with a HP-Ge detector.

Measurement at Tuebingen concluded without any detection of $^{166\text{m}}\text{Ho}$.

Background is the limiting factor.

An upper limit of 3.0 mBq can be inferred from the absence of expected $^{166\text{m}}\text{Ho}$ lines.



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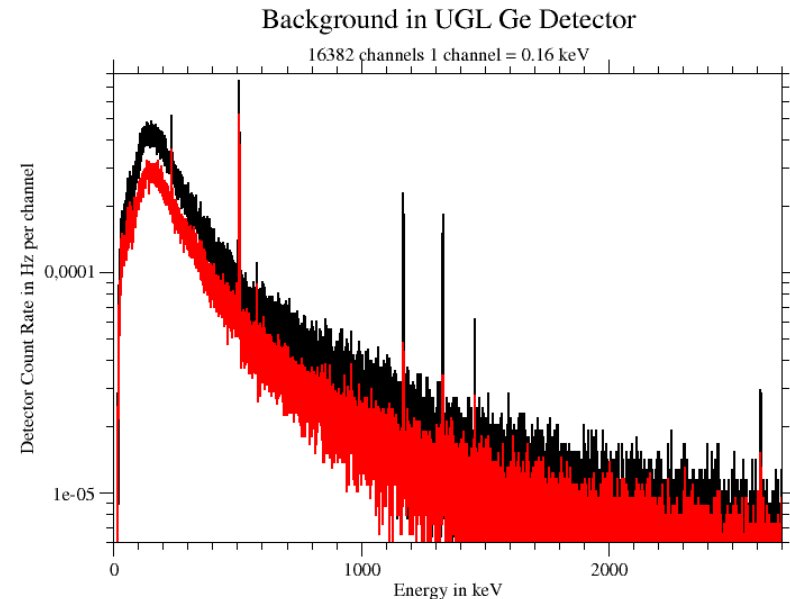
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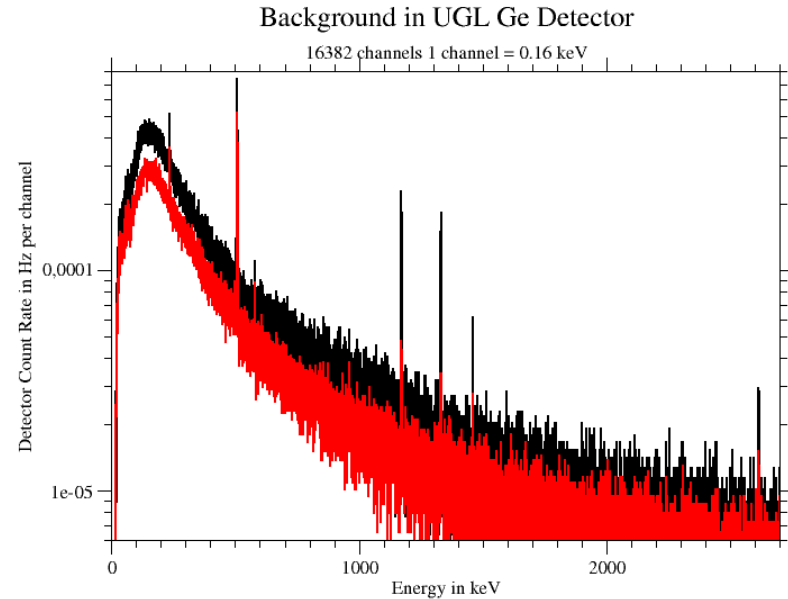
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Neutron activation analysis is started when the measurement at Dresden is finished.



Monte Carlo simulations are an important tool for the investigation of detector performance and background effects.

In our case we will use the standard framework of GEANT4 for the simulation and ROOT for the data processing.

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- The energetic region of interest is rather low, 2–3keV only.
- The detector geometry is unusual, the detector only measures $200\mu\text{m} \times 200\mu\text{m} \times 10\mu\text{m}$.
Large surface and large probability of incomplete energy collection of background events.

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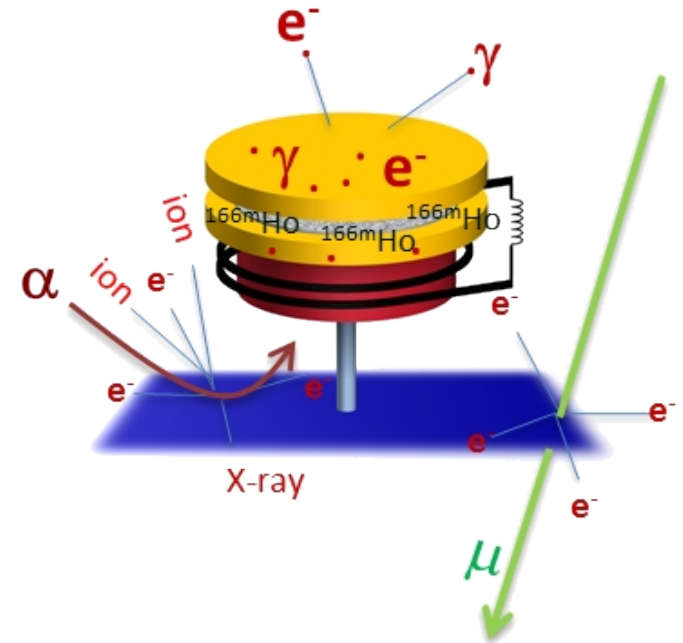
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- The propagation of the secondary particles in processes like fluorescence has to be checked.
- Exotic sources like the decay metastable isotopes, e.g. $^{166\text{m}}\text{Ho}$.

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The electromagnetic physics list of GEANT4 have been checked for their ability to produce the full spectra of fluorescence X-rays, Auger electrons and particle induced X-rays (PIXE).

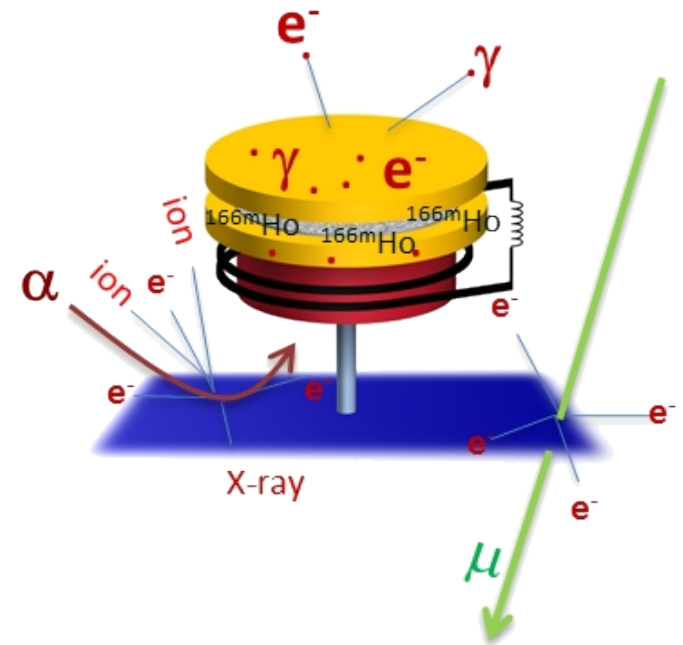
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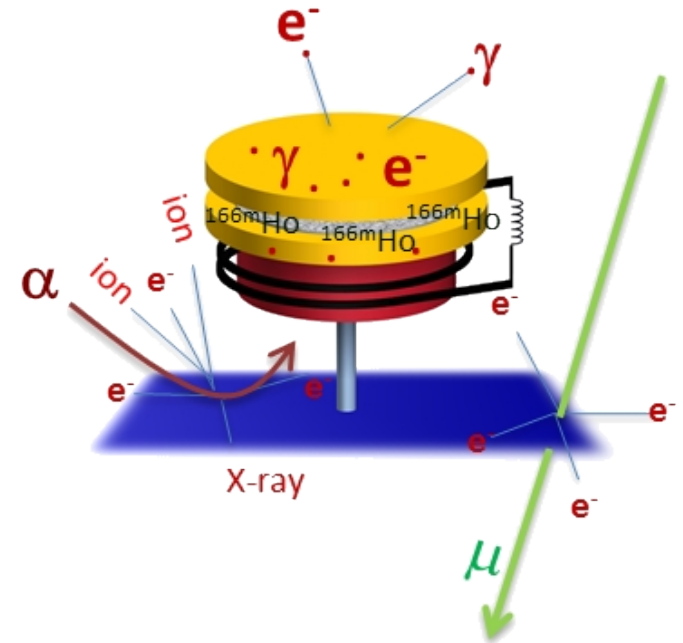
Both the Penelope physics list and the LivermoreEM physics list produce secondary particles in fluorescence, PIXE and Auger.

We selected the LivermoreEM list since it includes more atomic shells for its calculation.

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The simulation must be capable of handling the decay of metastable isotopes.

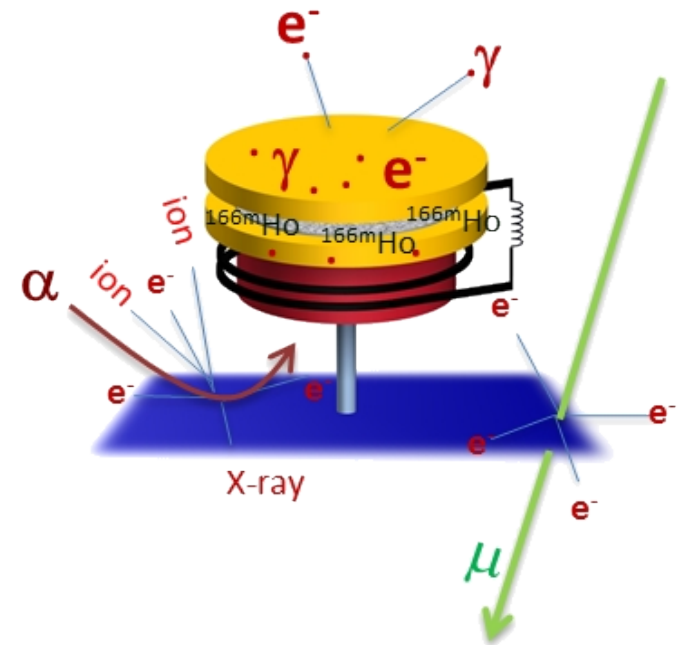
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However, the decay of metastable isotopes is not possible at the moment, due to some glitch in the definition of metastable isotopes in GEANT4 and the processing of these in the decay process.

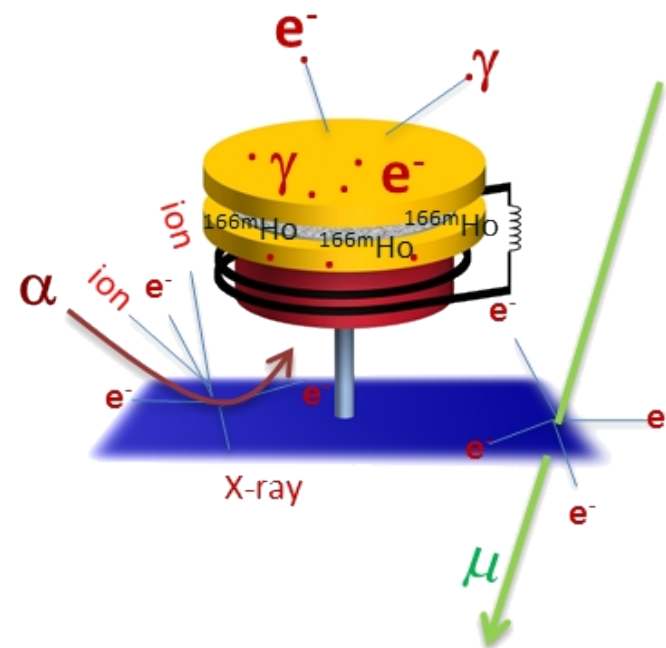
The decay process has been changed to allow the decay of metastable isotopes again.

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The large surfaces to volume ratio of the ECHO detectors make them sensitive to the secondary radiation of decays in the surroundings.

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The effect of the secondaries on the detector sensitivity has to be investigated.



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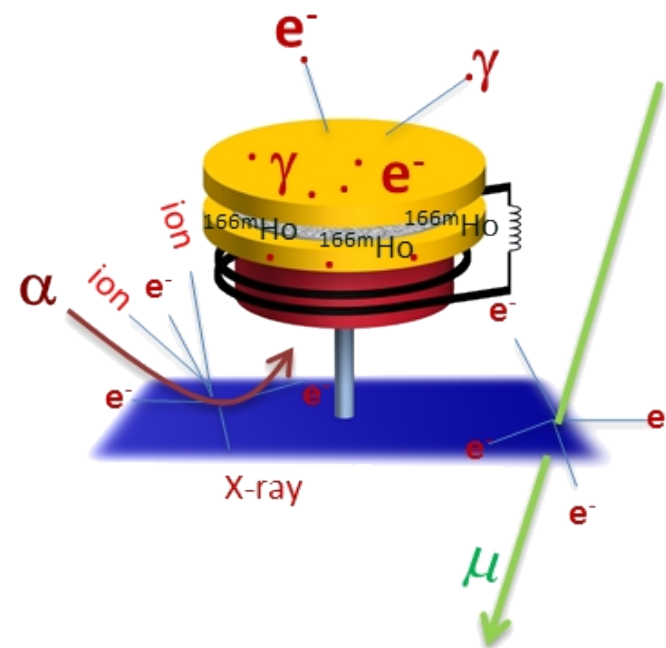
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Earlier studies of the effect of sputtered ions has shown that the production in GEANT4 to energies above 10 keV.

The goal here is to reduce the minimum energy of the production of sputtered secondaries and to compare the results with dedicated measurements.



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- The radioactive decay of metastable isotopes in GEANT4 is reestablished, allowing the simulation of the decay of ^{166m}Ho .
- An ECHO detector is currently moved to Modane underground laboratory to investigate its operation without cosmogenic interference.