Background Control and Reduction for the ECHo Experiment

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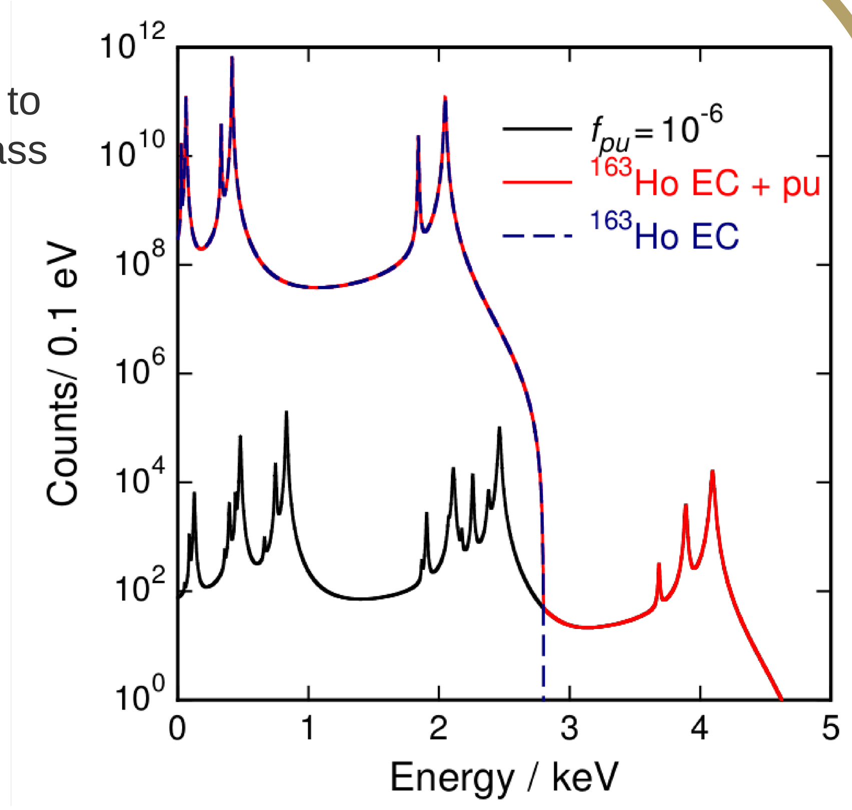
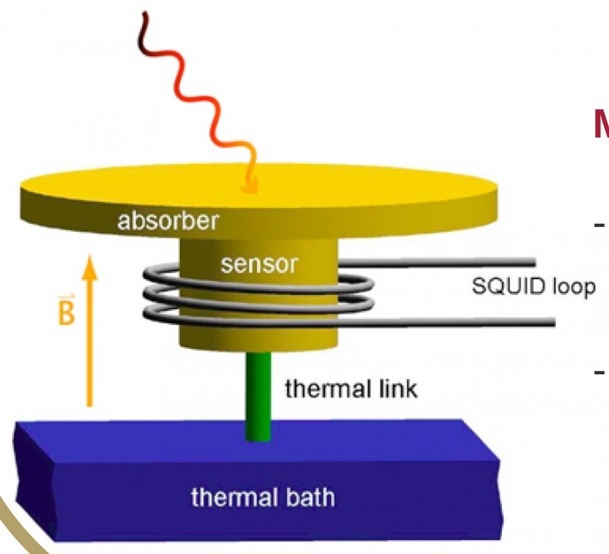
Introduction

Control of the background around 2.8 keV is crucial to reach sub-eV sensitivity on the electron neutrino mass



Possible background sources

- Intrinsic background source: unresolved pile-up
- Possible co-implanted isotopes like Ho-166m
- Ambient radioactivity (K-40, Uranium chains, ...)
- Cosmic muons and muon induced particles



Methods to reduce background levels in the ECHo experiment

- Screening of materials used in detector fabrication and for the detector set-up
- Study of the the effect of the different background source through Monte Carlo simulations based on GEANT4

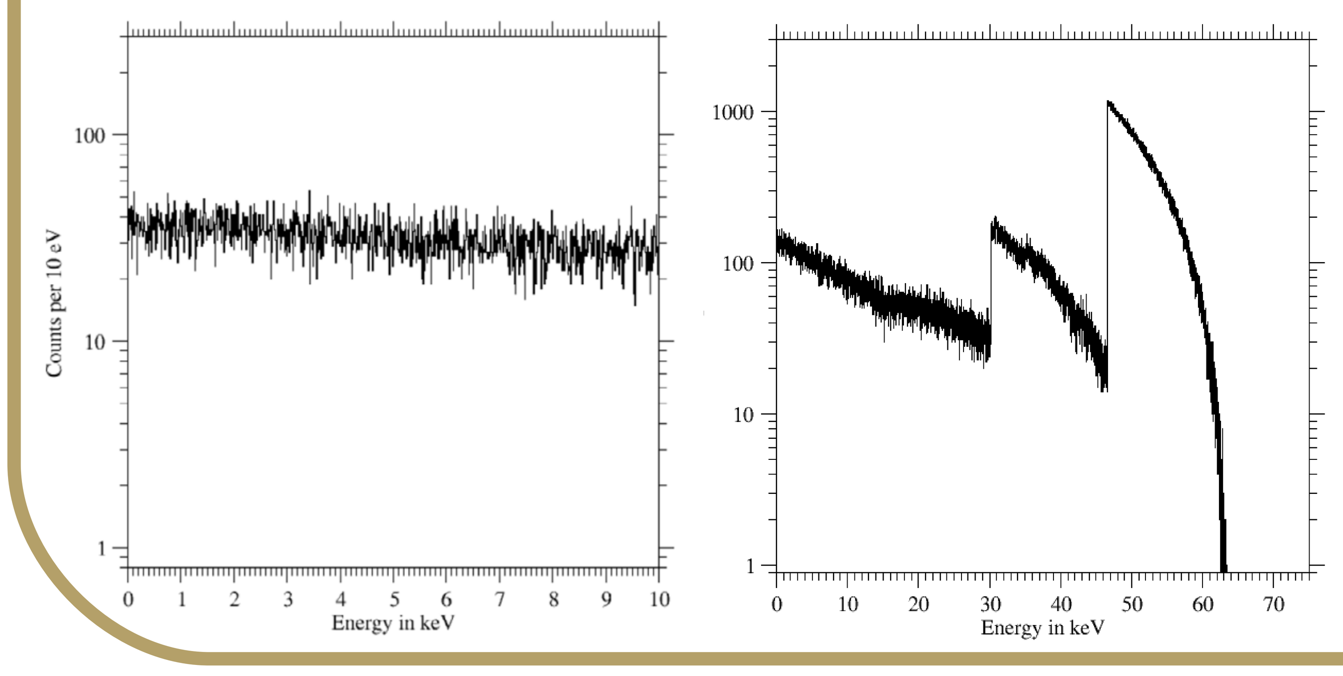
Monte Carlo Simulations

- The energy range which is interesting for the ECHo experiment E < 10 keV, is very low with respect to usual GEANT4 applications
- The typical particle absorber geometry of about 200 µm x 200 µm x 10 µm is tiny compared to standard size in high energy physics experiments
- The decay scheme of natural occuring radioactive nuclides is precisely characterized for energies larger than 100 keV but is not so well defined for the atomic de-excitation components
- The correct creation and propagation of secondary low energy particles produced in processes like flourescence, ion sputtering and other decay modes must be ensured in the simulation

Source	Location	Resulting upper contamination level, which would yield a rate (in ROI) comparable to half the Ho-163 rate (in ROI)
K-40	On detector surface	0.15 Bq / cm²
K-40	On top of PCB	40 Bq / cm² (unrealistic)
K-40	In PCB bulk	800 Bq / cm³ (unrealistic)
Pb-210	In absorber bulk	5 mBq
Pb-210	On detector surface	2.5 mBq / cm²
U chain	In Cu shielding	> 100 Bq / kg (unrealistic)

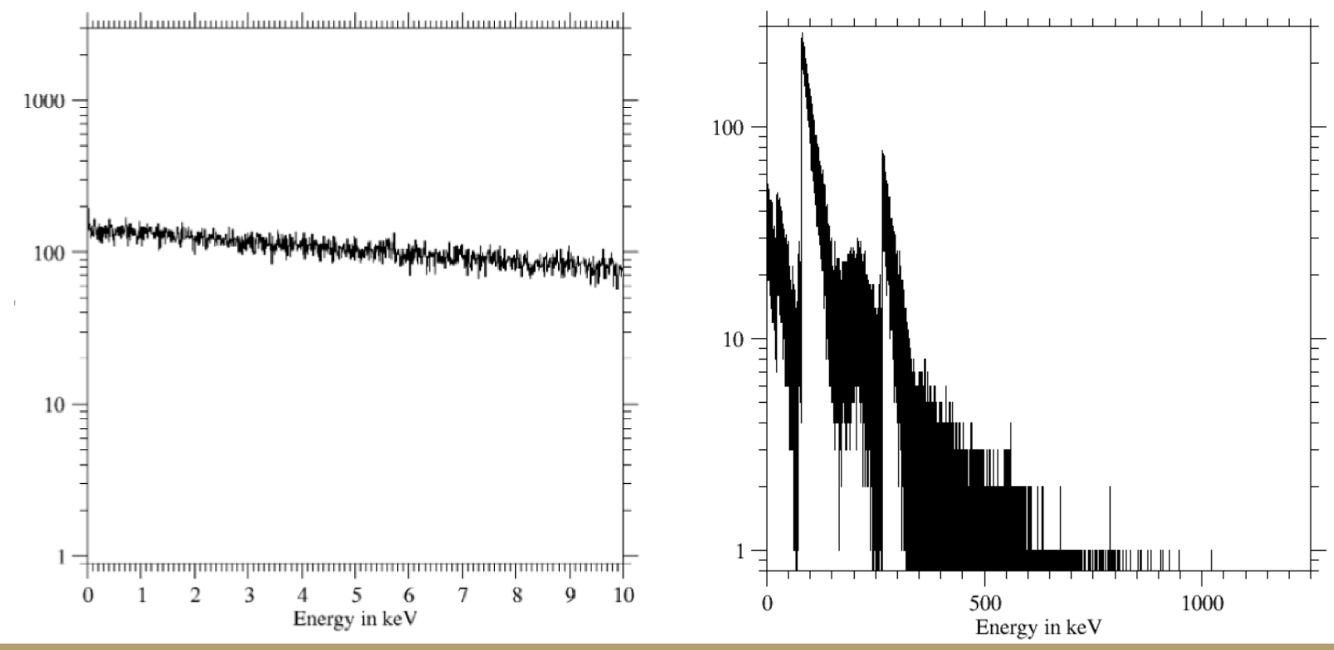
Background contribution due to co-implanted Ho-166m

- Ho-166m is co-produced within the Ho-163 production via neutron irradiation of erbium
- Beta-decay to excited states of Er-166
- Fraction Ho-166m to Ho-163 must be kept smaller than 5e-8



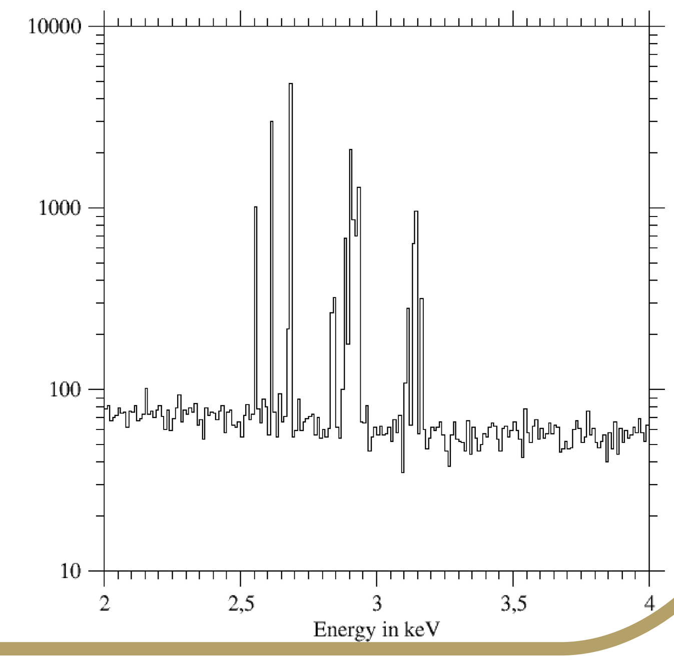
Background contribution due to Pb-210 on detector surface

- Pb-210 is produced over the uranium series, specially over the decay and decay products of Rn-222 in the air
- Beta-decay to Bi-210 (to Po-210 (beta minus)) to Pb-206 (alpha))
- Flat spectrum around region of interest



Background contribution due to K-40 on detector surface

- K-40 can be found in natural potassium
- EC and beta-plus-decay
- Auger electrons and X-rays around the region of interest



Material Screening

Sample	K-40	Tl-208	Pb-212	Bi-215	Pb-214	Ra-226	Comment
Gold flakes from Ho implantation							Combined upper limit of A(Ho-166m) < 0.65 mBq
Ho-166m implanted chip							Ho-166m activity of 7 mBq measured
Cryostat copper [mBq / kg]	< 480	< 80	< 190		< 96	< 600	No signal, 50% internal Ge detector background
Cryoperm [mBq / kg]	< 335	< 25	< 45	< 170	< 40	< 200	No signal, 50% internal Ge detector background
Connectors [mBq / kg]	5600	1600	10800	10800	10800	8000	As bulk contamination
Connectors [mBq] p.p.	3	1	6	6	6	4	Contamination per piece
Circuit board [mBq / kg]	625	4800	16300	8700	8000	5300	As bulk contamination
Circuit board [mBq / cm²]	0.45	1.39	4.75	2.53	2.33	1.54	Contamination per cm²
Cable [mBq / cm²]	0.49						Contamination per cm²

Muon Veto

- 24 plastic scintillators panels
- Read out by SiPMs
- Programmable logic by using a micro controller
- Efficiency of about 80 %
- Design ensures that muons passing close to the detector arrays have to pass at least two muon veto modules