The Electron Capture in ^{163}Ho Experiment

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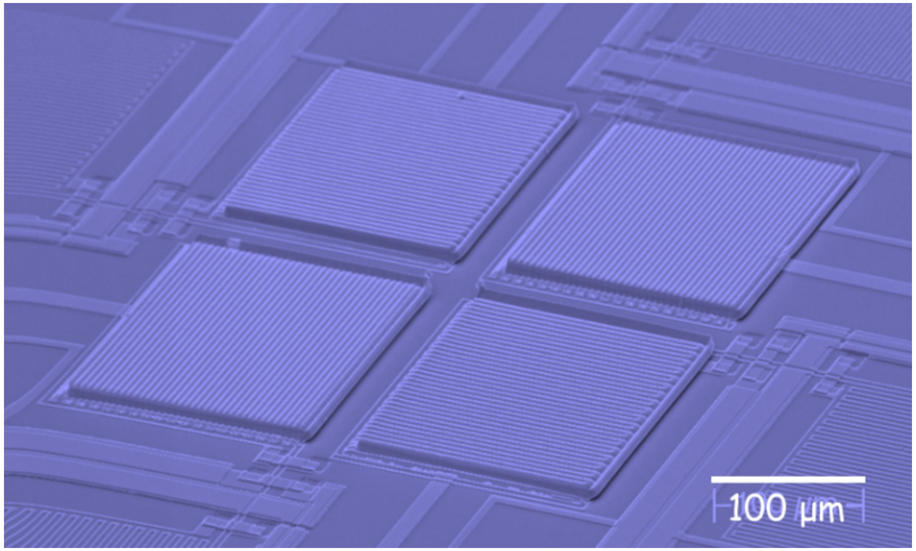
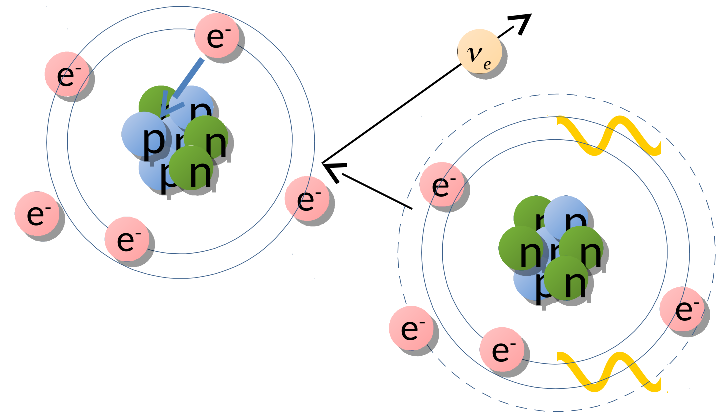
on behalf of the
ECHo collaboration

TAUP 2017
24th – 28th July, 2017, Sudbury



^{163}Ho is a nuclide which decays via an electron capture with the lowest known Q-value (Q_{EC} = 2833 eV, $\tau_{1/2}$ = 4570 years).

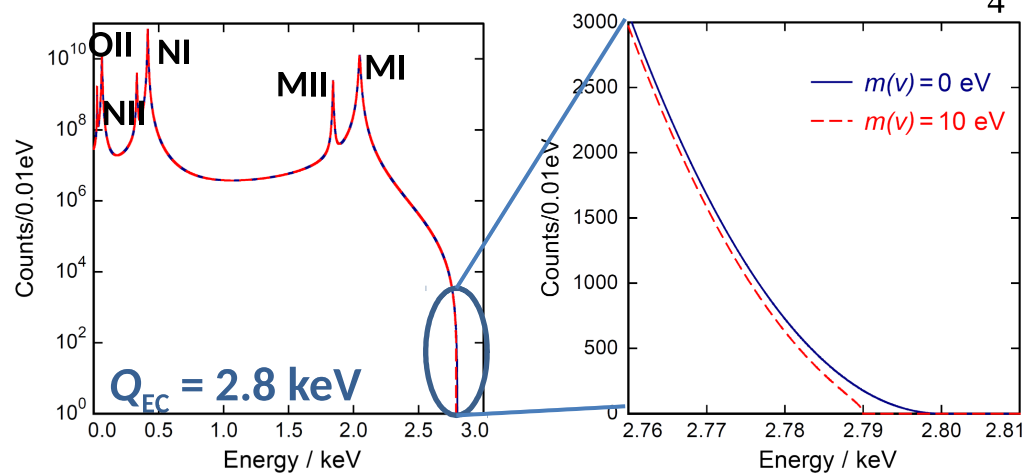
The decay energy is released via atomic deexcitations, i.e. X-rays and Auger electrons.



Measure the full energy release (apart from the neutrino ofc.) with a calorimetric measurement of a fully enclosed source.

$$\frac{dW}{dE_C} = A(Q_{EC} - E_C)^2\sqrt{1 - \frac{m_\nu^2}{(Q_{EC} - E_C)^2}}\sum_H B_H\varphi_H^2(0)\frac{\frac{\Gamma_H}{2\pi}}{(E_C - E_H)^2 + \frac{\Gamma_H^2}{4}}$$

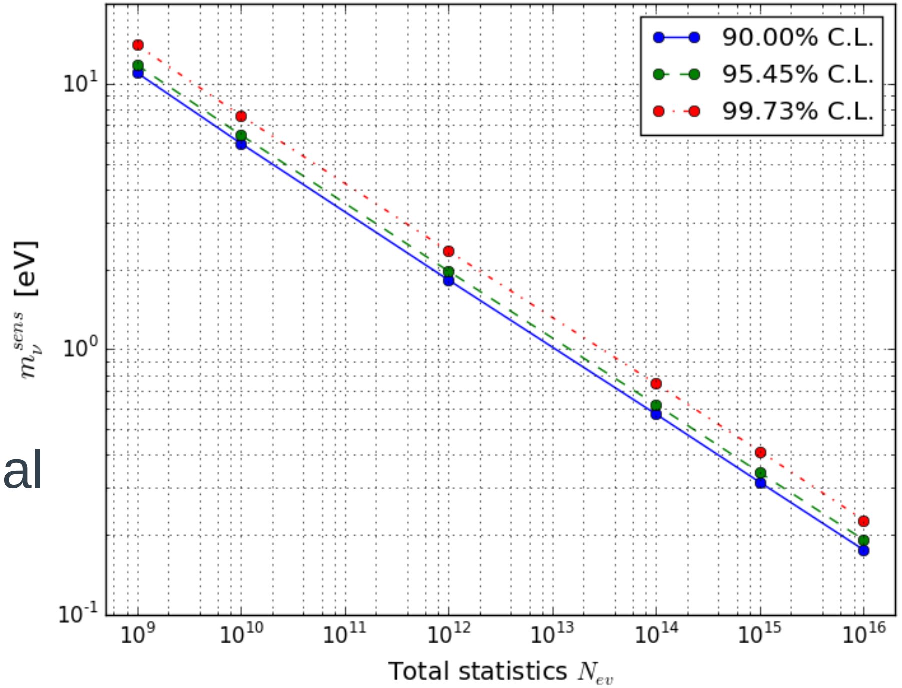
A non zero neutrino mass deforms the deexcitation spectrum.



^{163}Ho achievable sensitivity

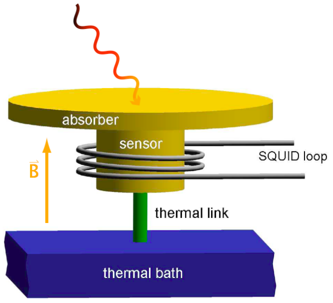
To reach sub–eV with an experiment based on ^{163}Ho, the following features are required:

→ Large activity:
Only 6 x 10^{-13} decays fall within 1 eV of Q_{EC}.



→ Large number of detectors:
The pile–up fraction f_{pu} is proportional to the activity per detector.

→ Precise energy resolution in the region of Q_{EC}.



→ These requirements are achievable with arrays of low temperature calorimeters !

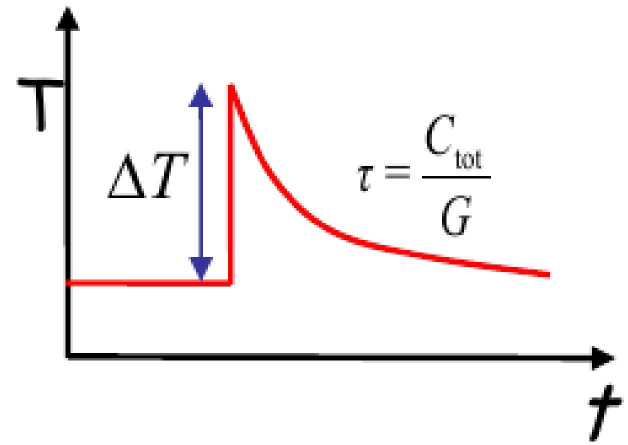
Low temperature micro calorimeters are characterized by:

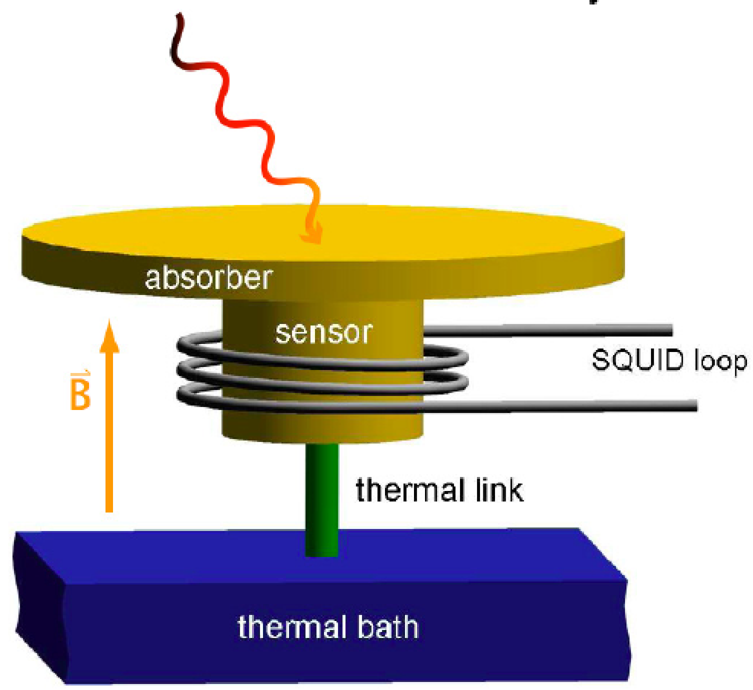
→ Very small volume

→ Operation below 100 mK
small specific heat
small thermal noise

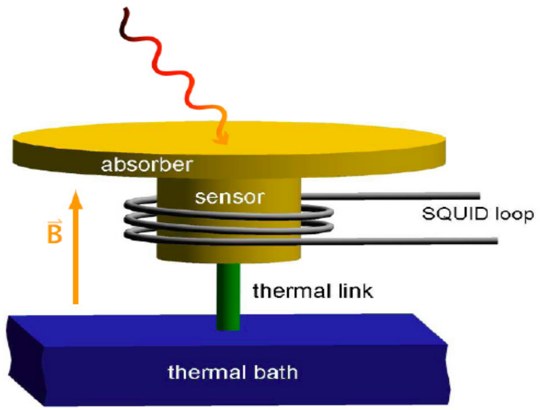
→ Very sensitive to temperature changes

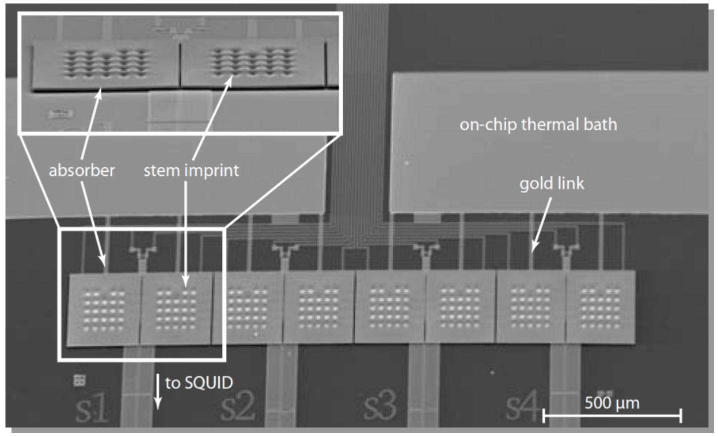
The ECHo detectors are metallic magnetic calorimeters (MMCs). A paramagentic sensor is located in a stab magnetic field.

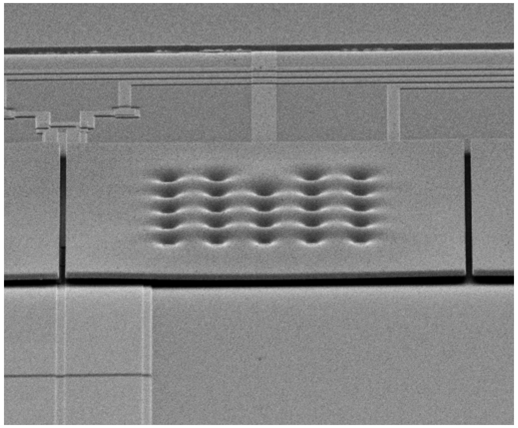


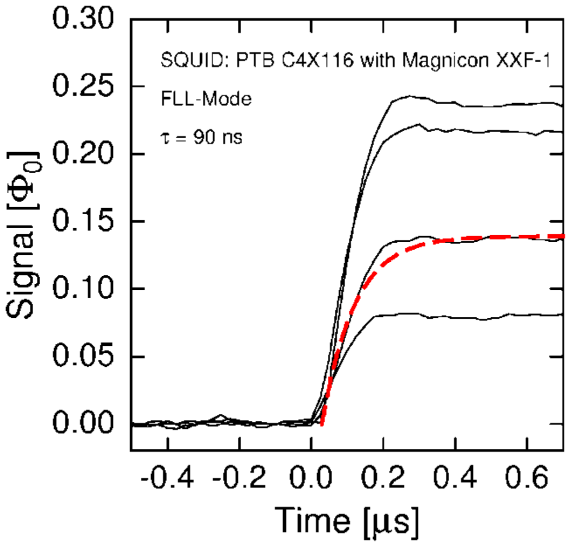


Metallic Microcalorimeters (MMCs)

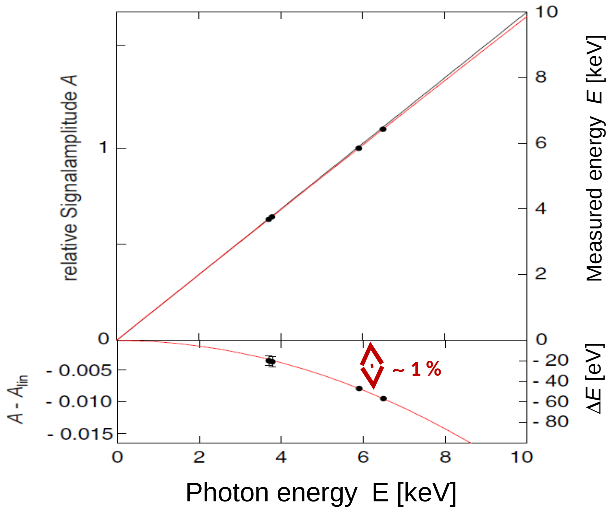




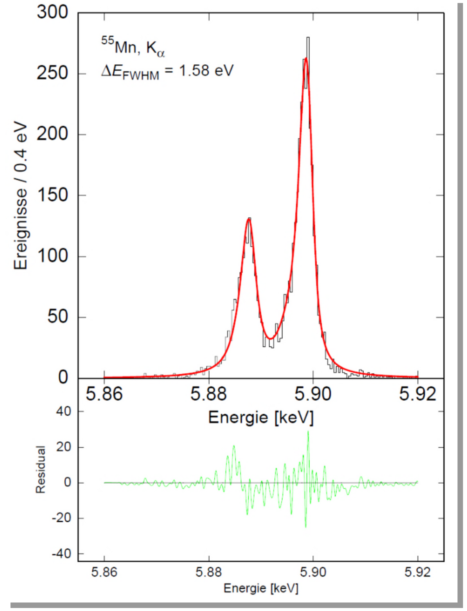




Rise Time: 90 ns



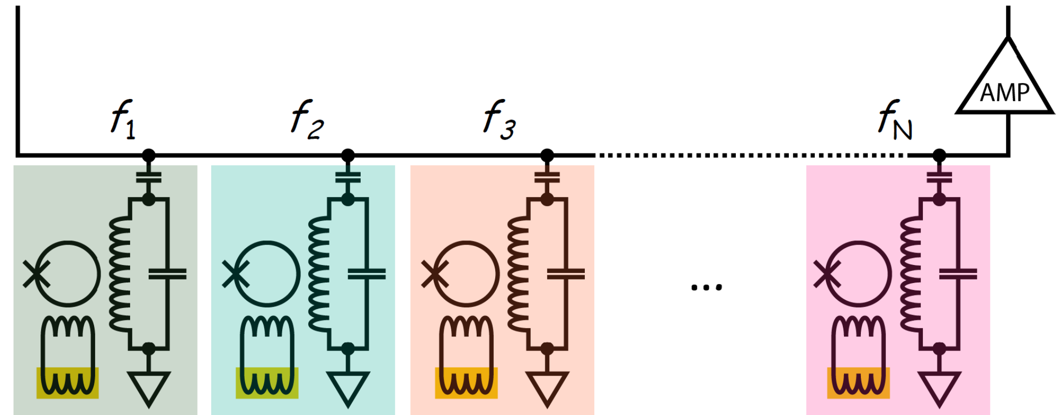
Non-Linearity < 1%@6keV



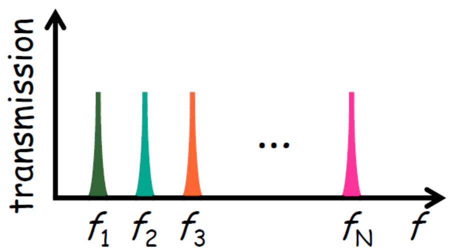
ΔE_{FWHM} = 1.6 eV@6 keV

Microwave squid multiplexing

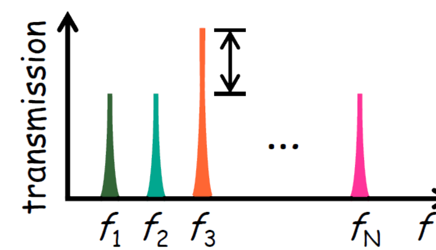
Microwave squid multiplexing allows to read out 100–1000 detectors with a single HEMT and two coax cables.



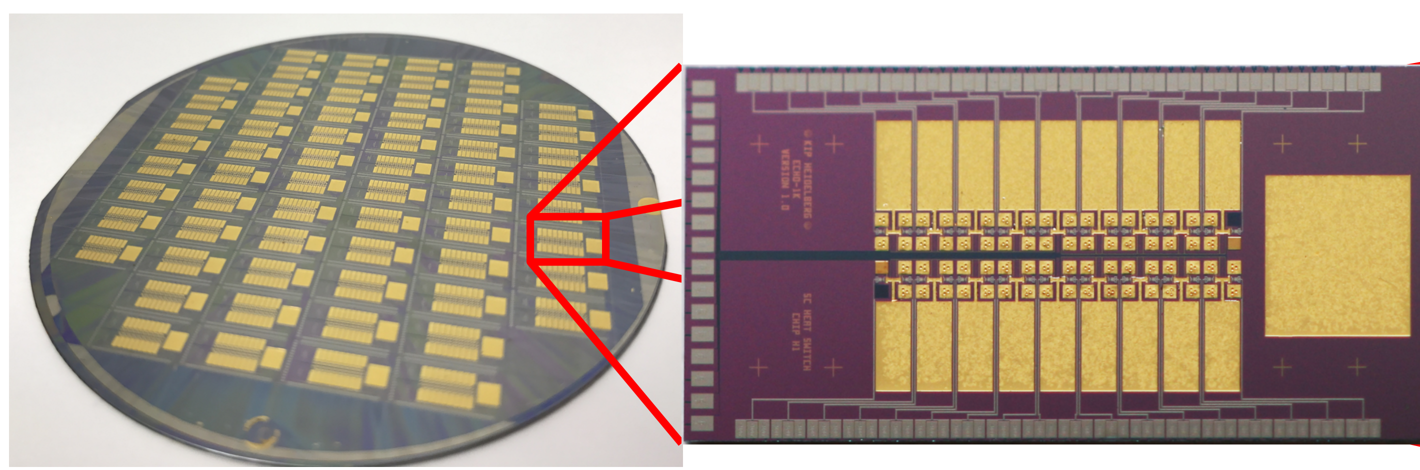
No signal



Signal in detector 3



Prototype has been successfully produced and tested for a 64 pixel chip.

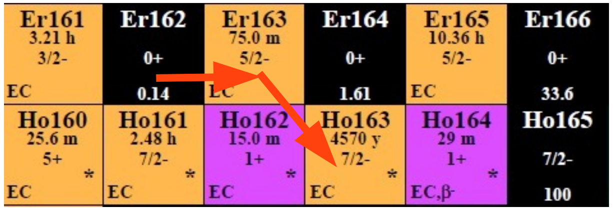


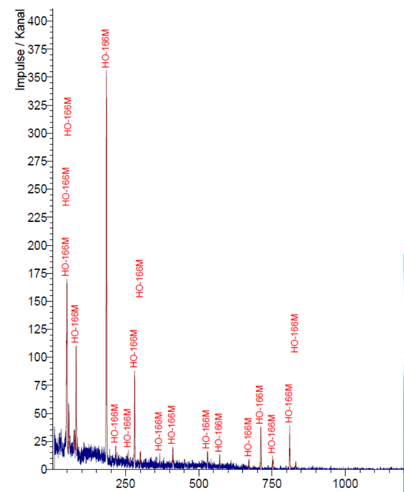
For a MBq activity , 10^{17} atoms of ^{163}Ho are required.

Several production parts:

We use (n,γ) production:

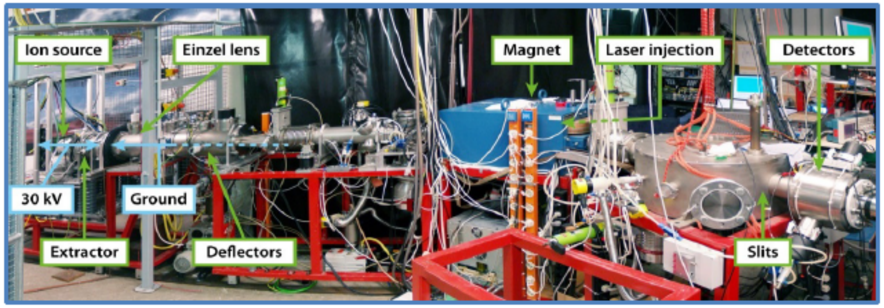
→ large cross–section
→ long–lived radiocontaminants





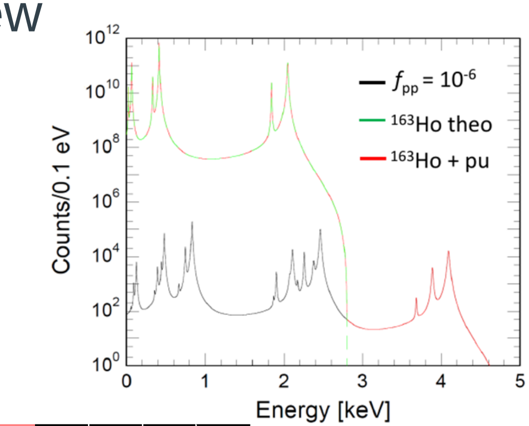
Sample has been irradiated at ILL, Grenoble.
10^{18} atoms of ^{163}Ho are available.

Excellent chemical separation leaves only ^{166m}Ho contamination at 10^{-4} fraction.



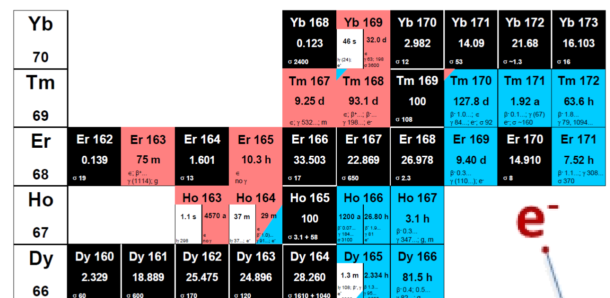
^{166m}Ho fraction is further reduced to 10^{-9} by offline mass separation at RISIKO, Mainz and ISOLDE, CERN.

Low energy backgrounds for the ECHo experiment are a new frontier:



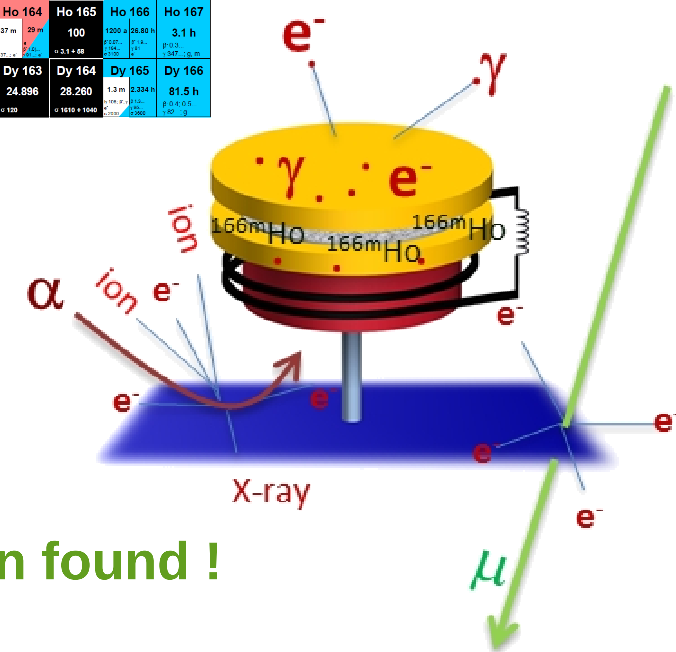
→ Irreducible background due to pile–up.
Depends on the activity of ^{163}Ho.

→ Bulk contamination of the detectors.
Dominated by ^{166m}Ho.



→ Ambient radioactivity.
Dangerous due to the secondary radiation, ^{40}K and ^{210}Pb.

→ Cosmogenics.
A muon veto system is developed, tested and ready to be installed.



So far no critical background contribution has been found !

New chip for ^{163}Ho implantation: maXs-20

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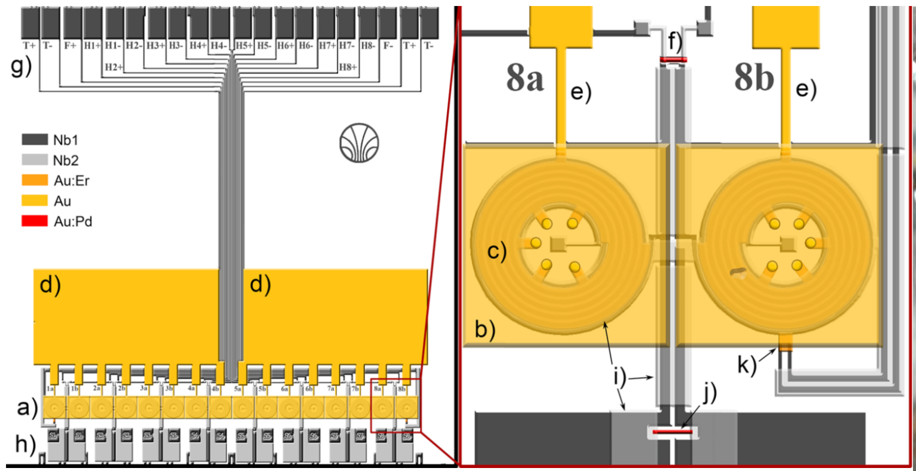
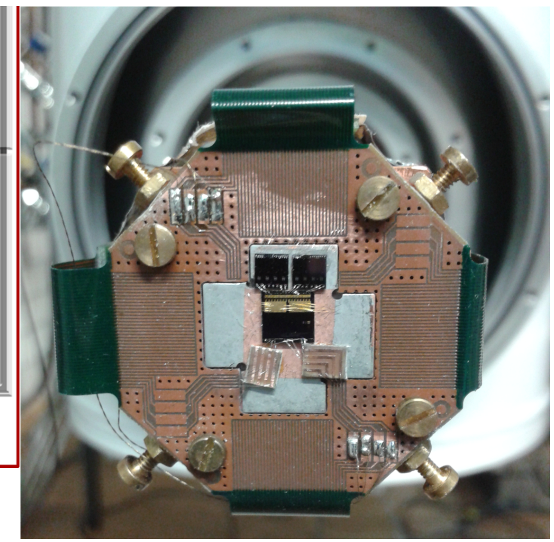
Stems connect absorber and sensor.

Up to 16 pixels per chip.





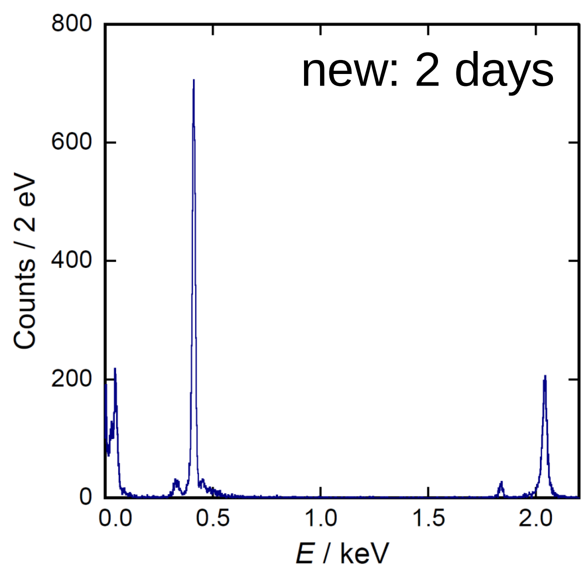
maXs-20 is a sandwich sensor design, absorber is connected via stems to the sensor.

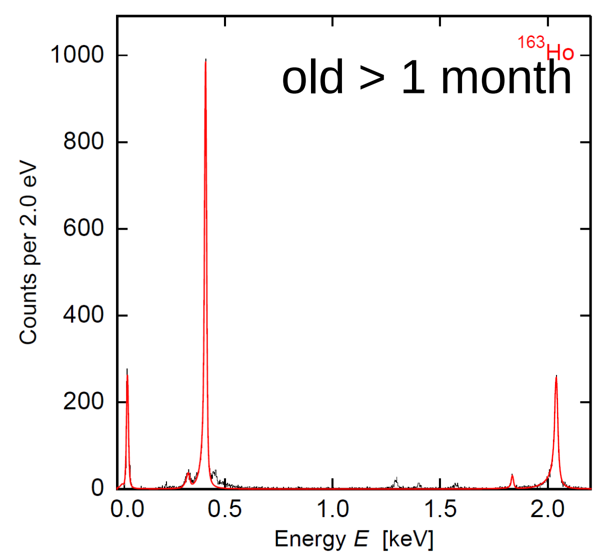
Results of a first test run:

$A(^{163}\mathrm{Ho}) \approx 0.1$ Bq per pixel

No radiocontamination seen

$\Delta_{\mathrm{FWHM}} \approx 5$ eV





Conclusion and Outlook

→ A high purity ^{163}Ho source has been produced.

→ ^{163}Ho ions have been implanted successfully in offline process at ISOLDE CERN and RISIKO.

→ 2 chips of 64 detector pixels each are going to be installed in the ECHo-1k phase.

→ No critical background sources have been encountered so far, all investigated contributions are expected to be well below the pile up of ^{163}Ho decays.

→ The muon veto for the ECHo experiment has been build and is waiting to be assembled on the experiment.

→ The cryostat for the ECHo experiment is fully comissioned.

→ In the next month, the data taking phase of ECHo–1k (1kBq of ^{163}Ho) starts.

Thank you for your attention !

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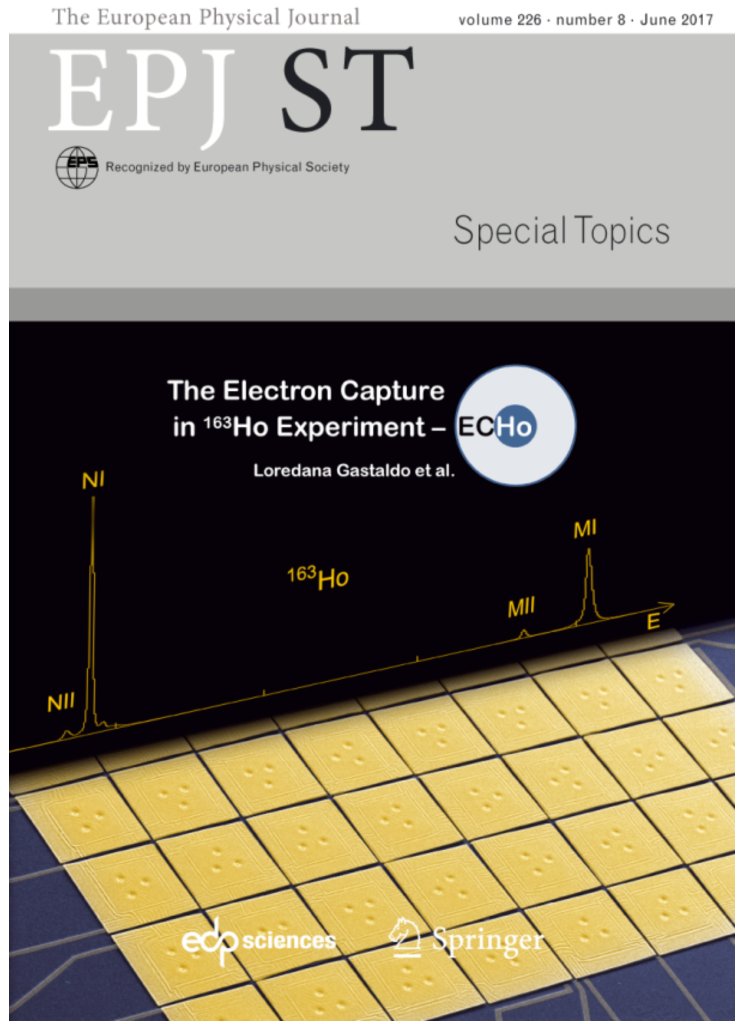

The ECHo Collaboration, EPJ-ST 226-8 (2017) 1623