Embedding of ^{163}Ho and ^{166m}Ho in energy absorbers of low temperature metallic magnetic calorimeters

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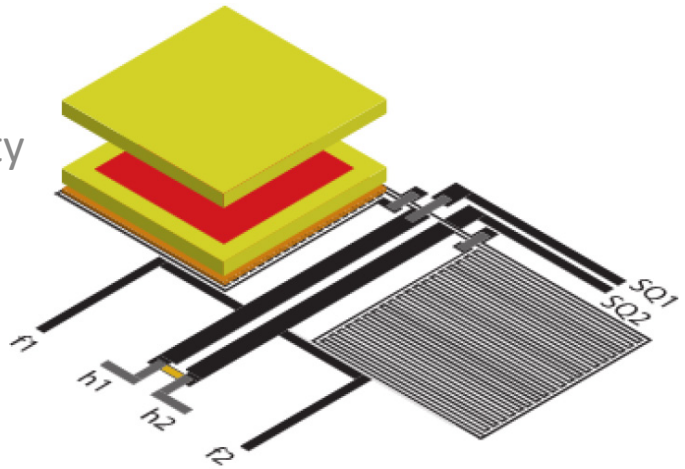
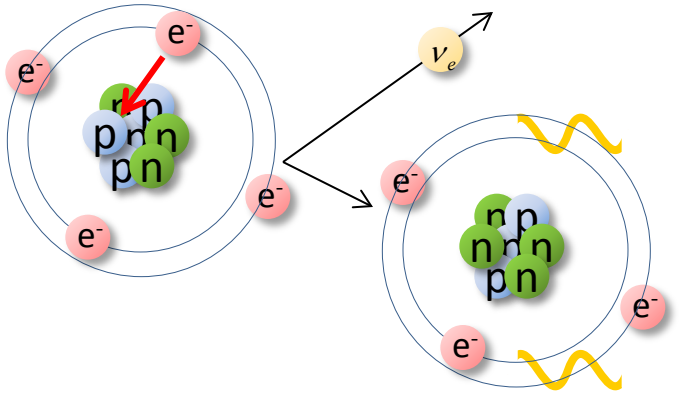


Electron Capture and electron neutrino mass



A non- zero neutrino mass affects the de-excitation energy spectrum

Atomic de-excitation:

- X-ray emission
- Auger electrons
- Coster-Kronig transitions

} Calorimetric measurement

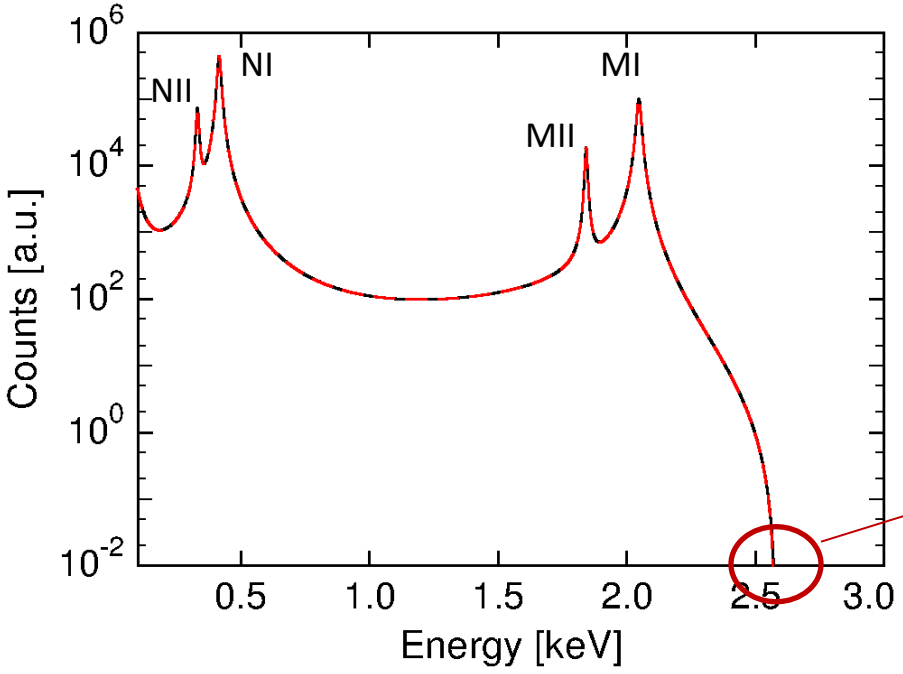
$$\frac{dW}{dE_C} = A(Q_{EC} - E_C)^2 \sqrt{1 - \frac{m_\nu^2}{(Q_{EC} - E_C)^2}} \sum_H B_H \varphi_H^2(0) \frac{\frac{\Gamma_H}{2\pi}}{(E_C - E_H)^2 + \frac{\Gamma_H^2}{4}}$$

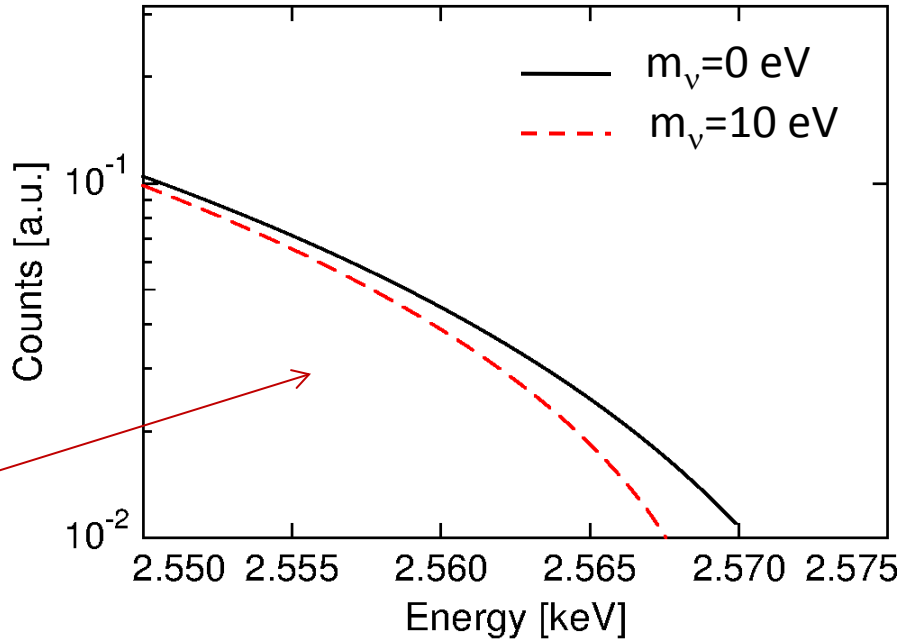
The case of ^{163}Ho

$$^{163}_{67}\mathrm{Ho} \rightarrow {}^{163}_{66}\mathrm{Dy}^{*} + \nu_e$$

$$^{163}_{66}\mathrm{Dy}^{*} \rightarrow {}^{163}_{66}\mathrm{Dy} + E_C$$

- $Q_{EC} \cong 2.5$ keV
- $\tau_{1/2} \cong 4570$ years





Present limit for the electron neutrino mass:
$m(\nu_e) < 225$ eV (95% C.L.) P.T. Springer et al., *Phys. Rev. A* **35**, 679 (1987)

The case of ^{163}Ho

$$^{163}_{67}\mathrm{Ho} \rightarrow ^{163}_{66}\mathrm{Dy}^{*} + \nu_e$$

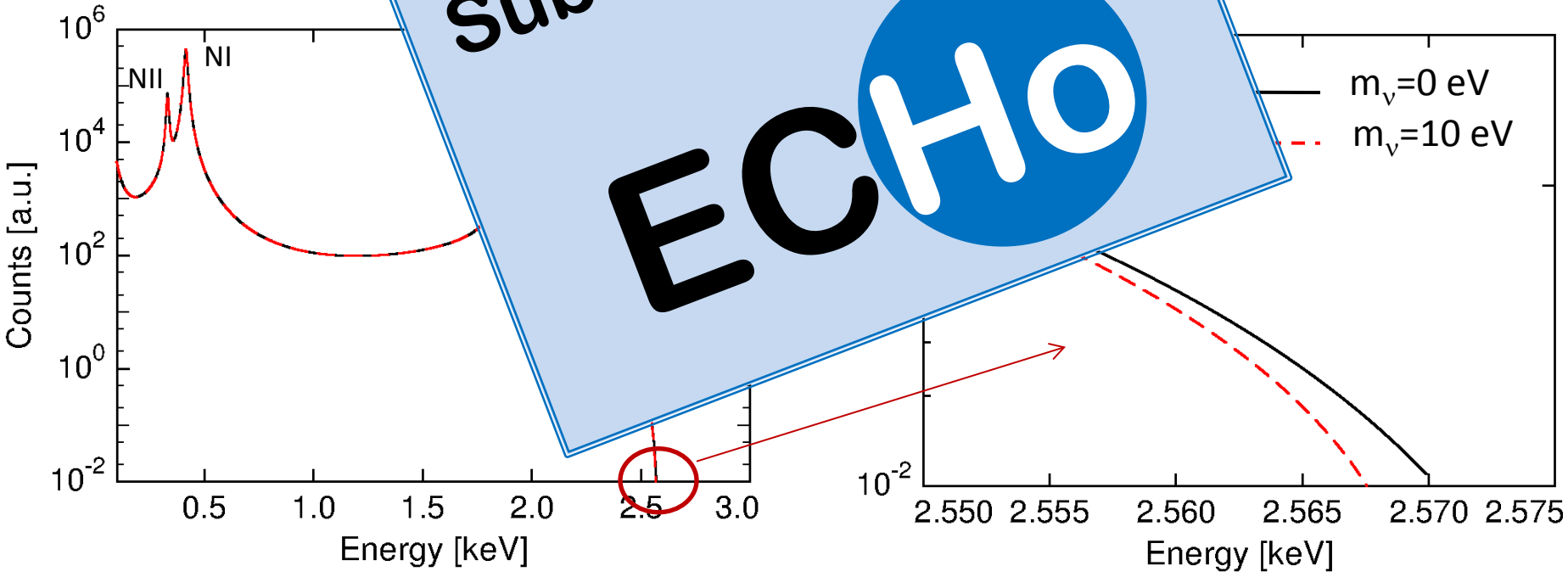
$$^{163}_{66}\mathrm{Dy}^{*} \rightarrow ^{163}\mathrm{D}$$

≅ 2.5 keV

4570 years

Sub-eV sensitivity

ECHo



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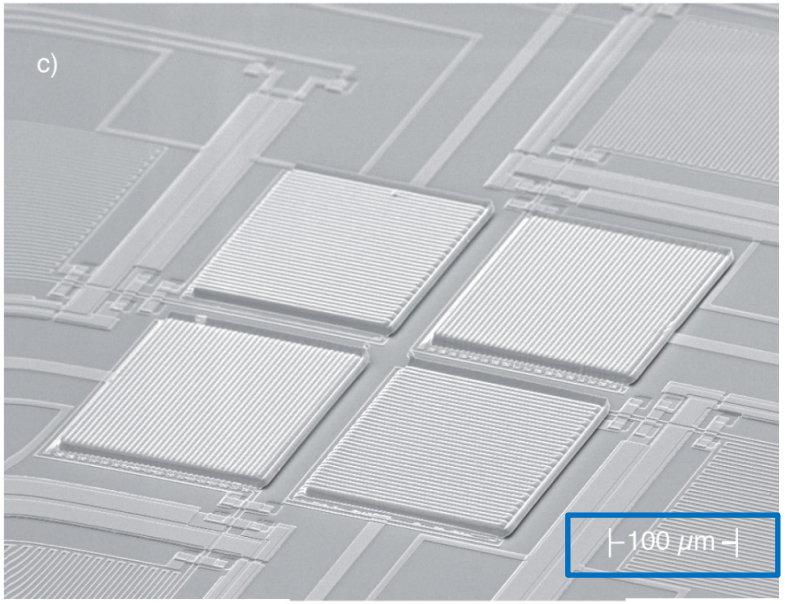
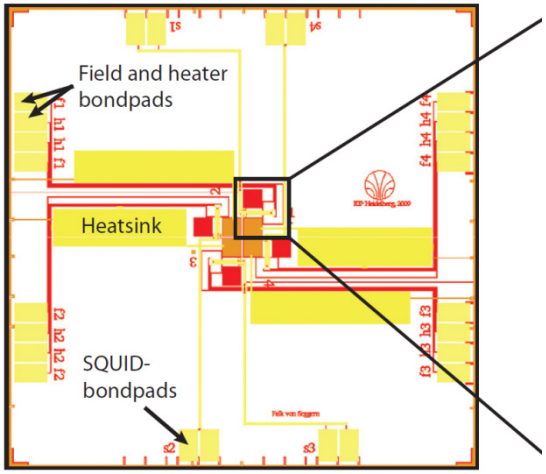
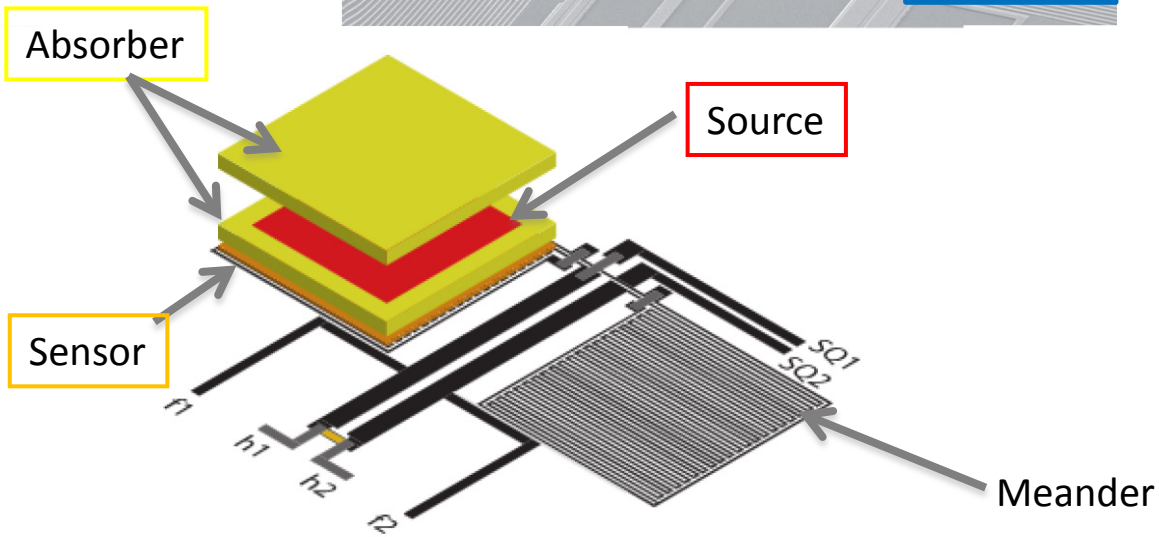
ECHo experiment: First detector prototype

- Low temperature metallic magnetic calorimters
- Absorber for calorimetric measurement → ion implantation @ ISOLDE-CERN
- Two pixels have been simultaneusly measured
- About 0.01 Bq per pixel



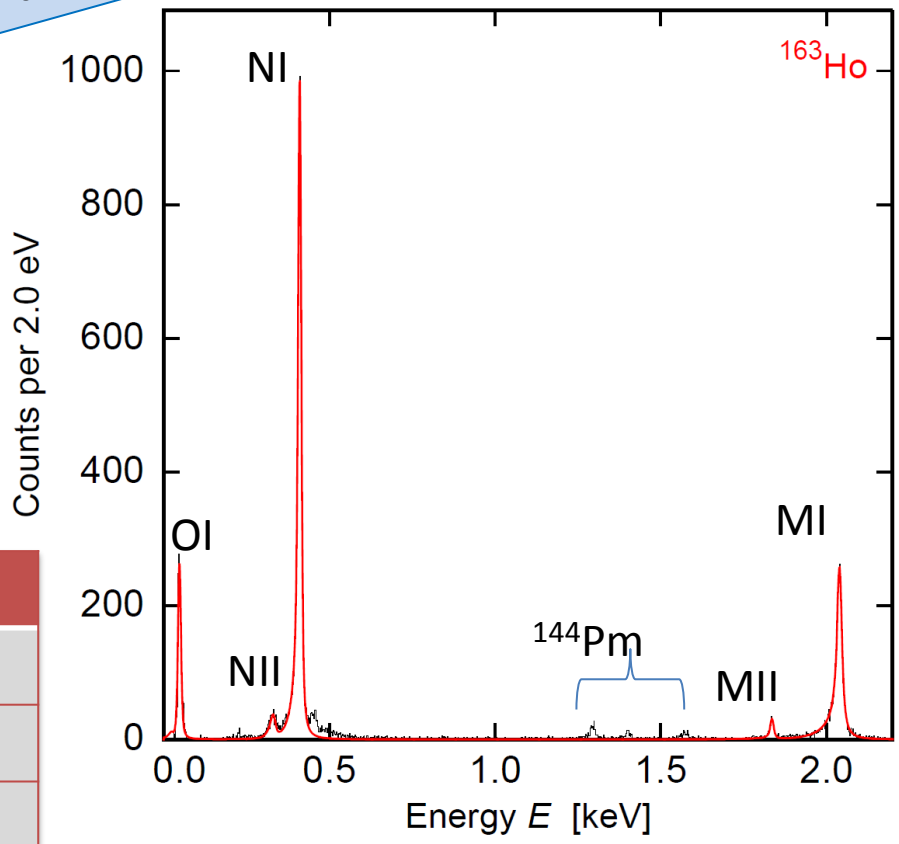




ECHo experiment: Calorimetric spectrum

- Rise Time ~ 130 ns
- ΔE_{FWHM} = 7.6 eV @ 6 keV
- Non-Linearity < 1% @6keV
- Most precise ^{163}Ho spectrum

Preliminary analysis



	E_H lit.	E_H exp.	Γ_H lit.	Γ_H exp
MI	2.047	2.040	13.2	13.7
MII	1.845	1.836	6.0	7.2
NI	0.420	0.411	5.4	5.3
NII	0.340	0.333	5.3	8.0
OI	0.050	0.048	5.0	4.3

Q_{EC} =(2.80±0.08) keV

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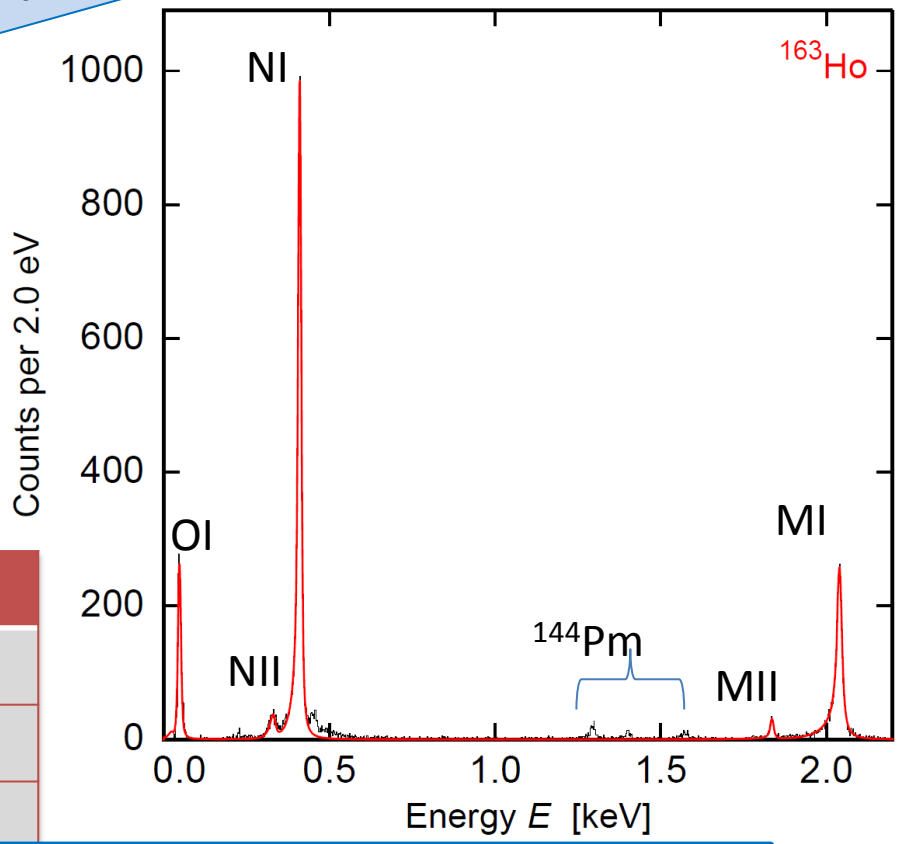
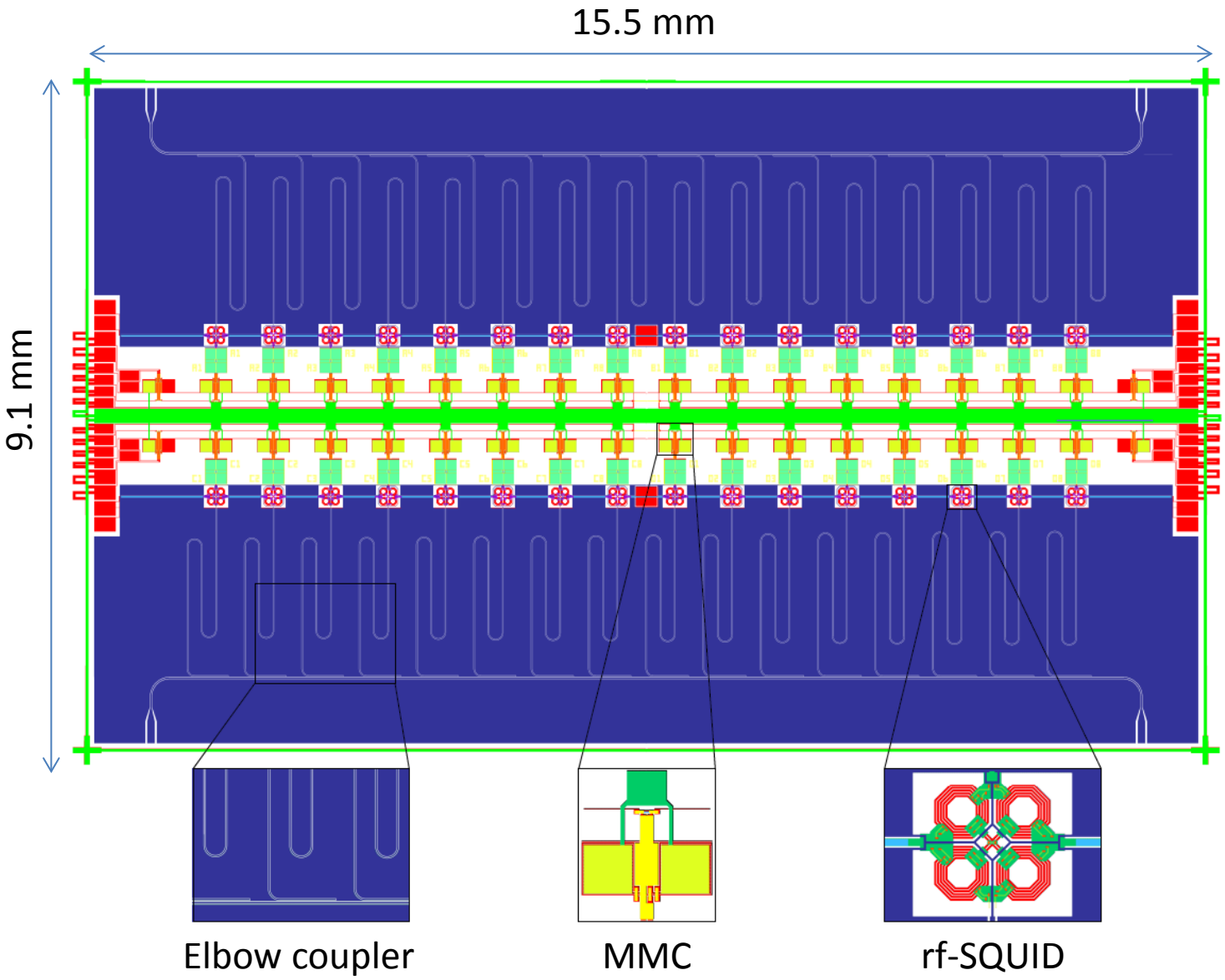


	E_H lit.	E_H exp.	Γ_H lit.	Γ_H exp
MI	2.047	2.040	13.2	13.7
MII	1.845	1.836	6.0	7.2
NI	0.420	0.411	5.4	5.3
NII	0.34			
OI	0.05			

Next step→ acquire more statistics with MMC arrays reduced radioactive contaminats

ECHo experiment: 64-pixel chip



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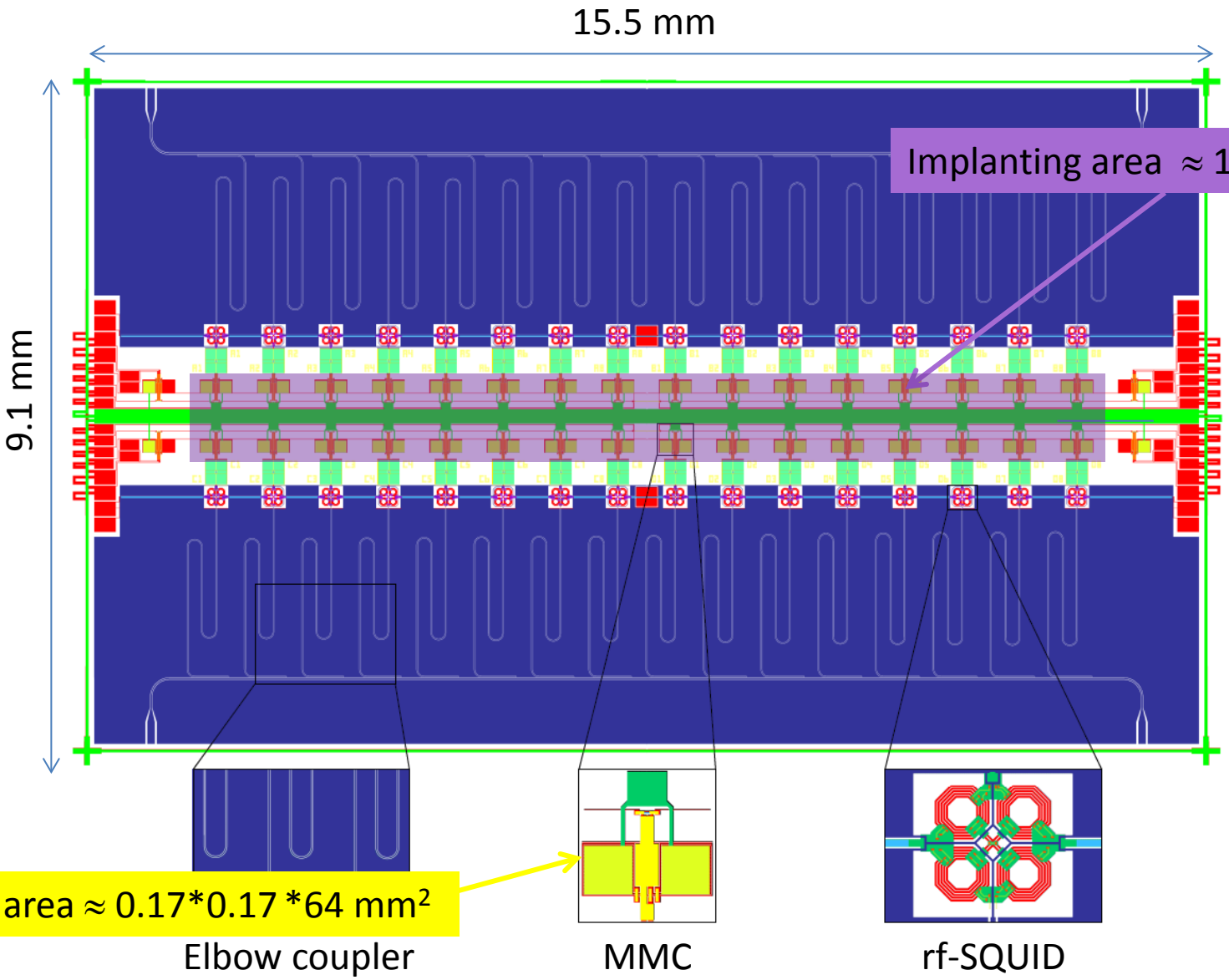

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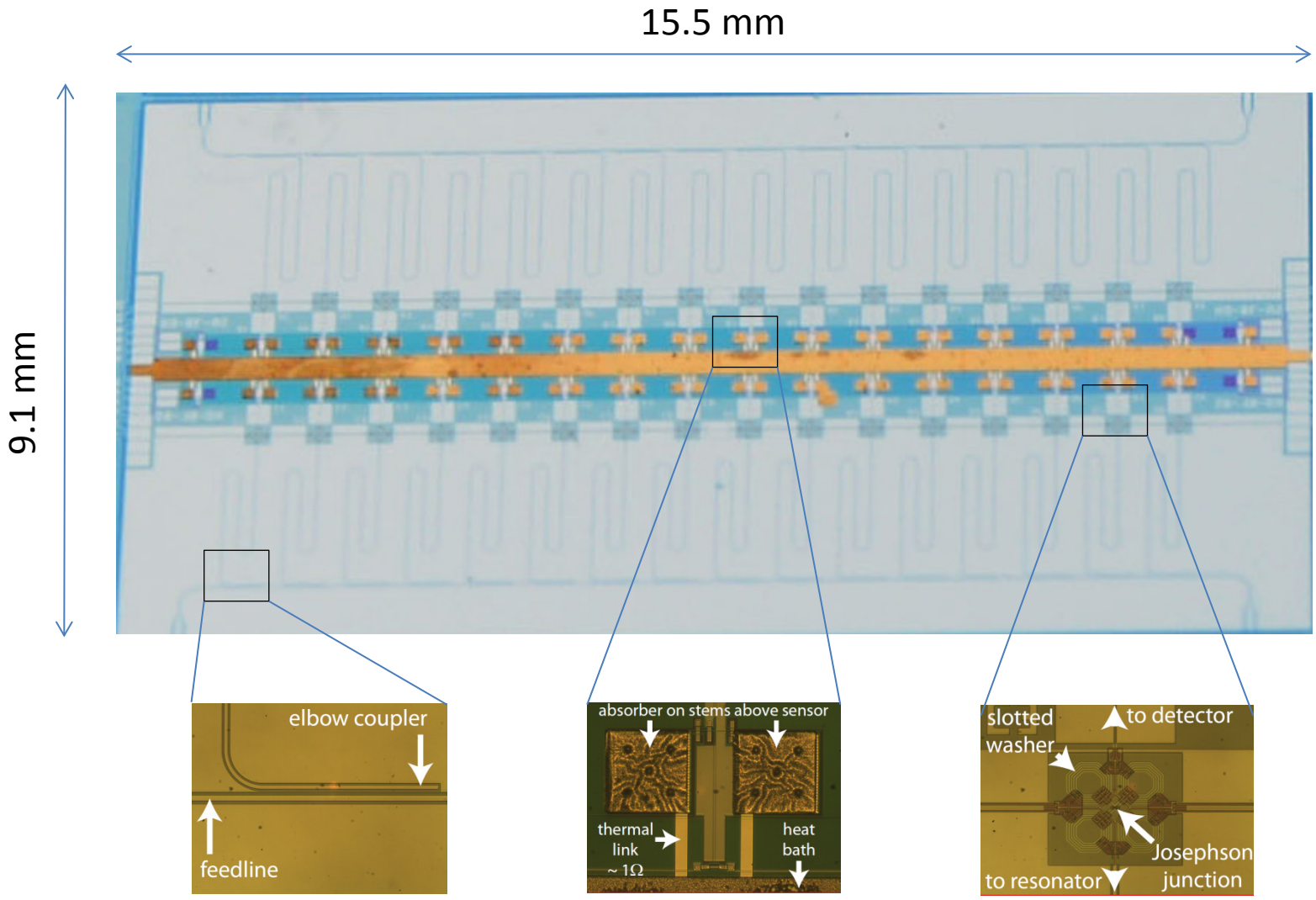


Elbow coupler MMC rf-SQUID

ECHo experiment: 64-pixel chip

Requests:

- Off-line implantation at GLM
- About 1 Bq per pixel
- For 2 chips with 64 pixels → 8 shifts

Source to Target:

- About 10^{16} ^{163}Ho ions in 8M HCl at Uni-Mainz
- Drying the source on Mo backing
- Ionization efficiency ≈ 10% (VADIS)

Goals:

- Study the shape of the ^{163}Ho EC spectrum
- Reaching neutrino mass sensitivity ≈10 eV

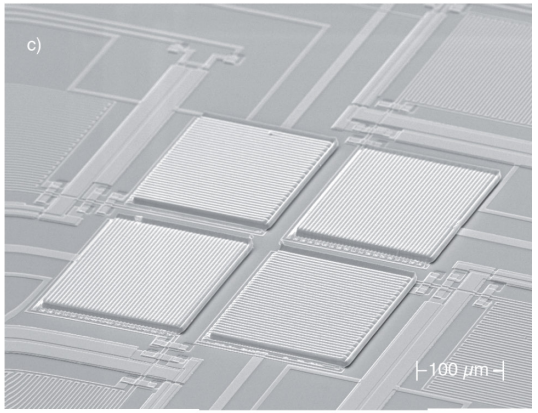
ECHo experiment: ^{166m}Ho Background

Requests:

- Off-line implantation at GLM
- About 1 Bq ^{166m}Ho implanted onto 4 absorbers → 1 shift

Source to Target:

- About 10^{14} ^{166m}Ho ions in HCl
- Drying the source on Mo backing
- Ionization efficiency ≈ 10% (VADIS)



Goal:

- Study the background due to ^{166m}Ho β decay in micro-calorimeter measurements

Summary

9 off-line shifts for implantation of ^{163}Ho and ^{166m}Ho

- 8 shifts for implanting ^{163}Ho
  onto two micro-structured chips with 64 pixels

- 1 shift for implanting ^{166m}Ho
  onto a chip with 4 pixels

Summary

9 off-line shifts for implantation of ^{163}Ho and ^{166m}Ho

- 8 shifts for implanting ^{163}Ho
  onto two micro-structured chips with 64 pixels

- 1 shift for implanting ^{166m}Ho
  onto a chip with 4 pixels

Thank you !

Back-up slides

Thank you!

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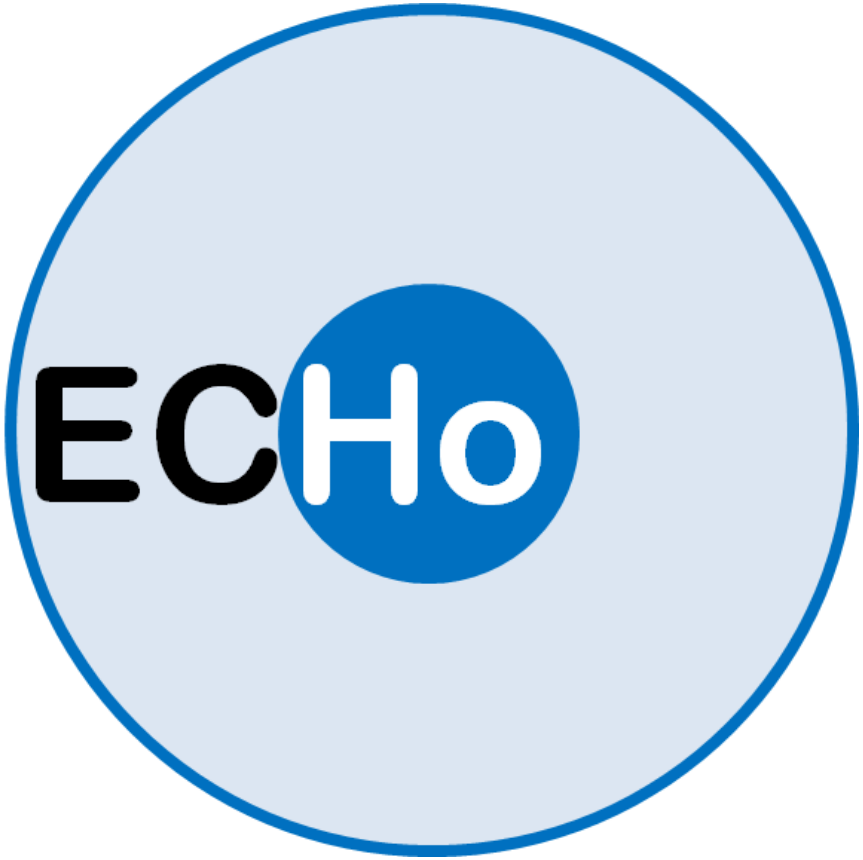


Neutrino mass sensitivity

$N_{ev} > 10^{14}$

$\Delta E_{FWHM} < 10$ eV

$\tau_r \sim 0.1$ μs

$A_\beta \approx 10$ s^{-1} $\longrightarrow$ $\geq 10^5$ detectors

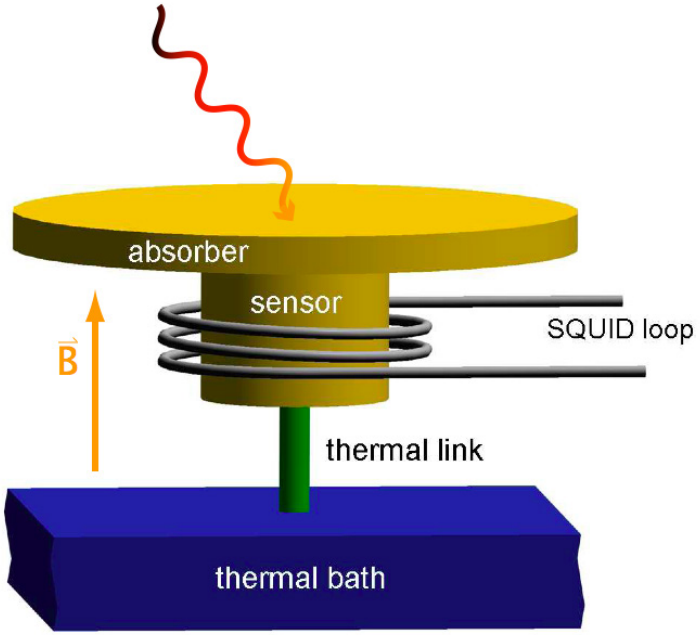
Low temperature

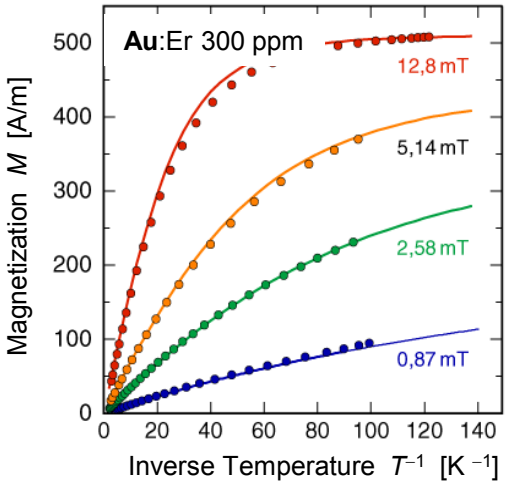
Metallic Magnetic Calorimeter

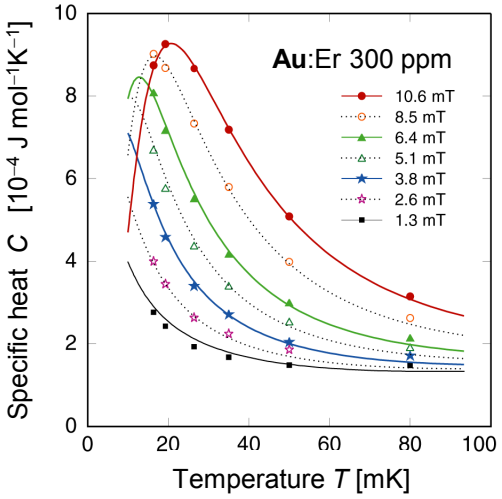
MMCs: Concept

- Paramagnetic Au:Er sensor

$$\Delta\Phi_s \propto \frac{\partial M}{\partial T}\Delta T \rightarrow \Delta\Phi_s \propto \frac{\partial M}{\partial T}\frac{E}{C_{sens}+C_{abs}}$$





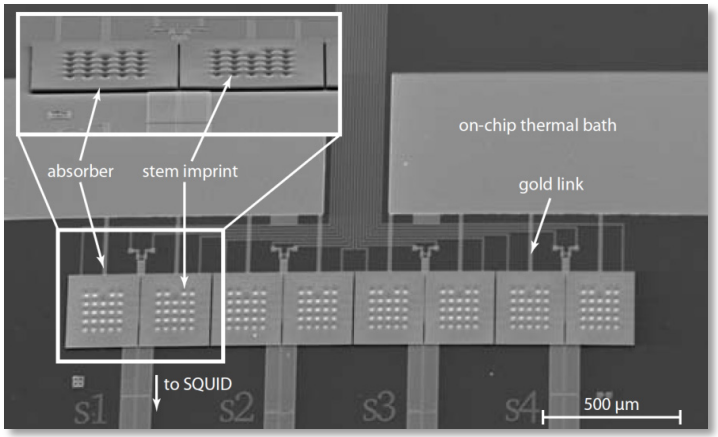


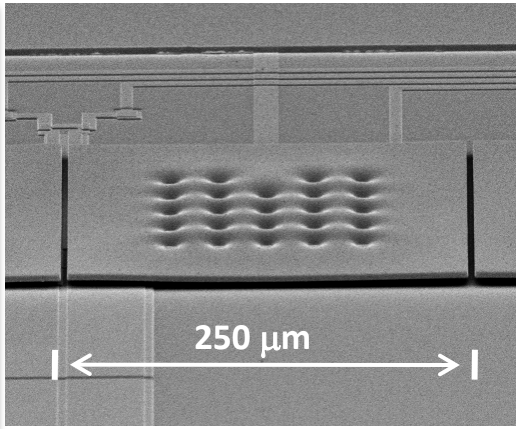
Main differences to calorimeters with resistive thermometers

no dissipation in the sensor

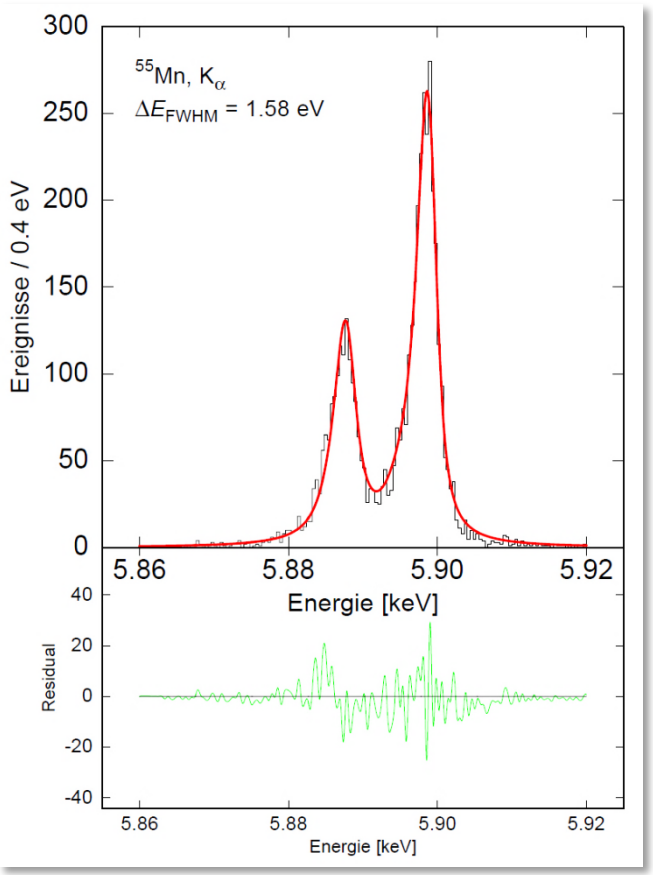
no galvanic contact to the sensor

MMCs: 1d-array for soft x-rays (T=20 mK)

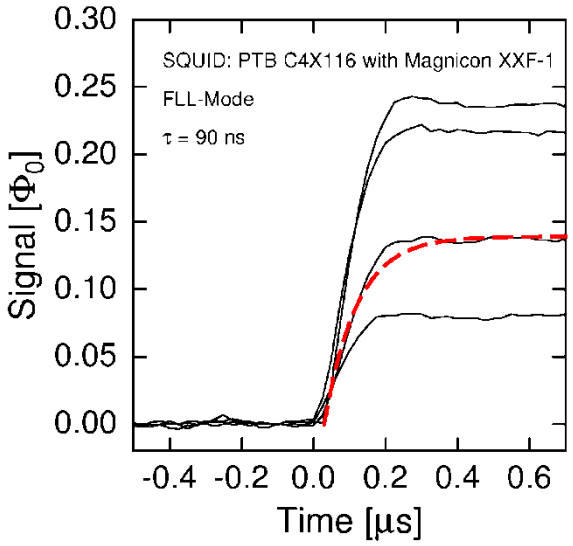




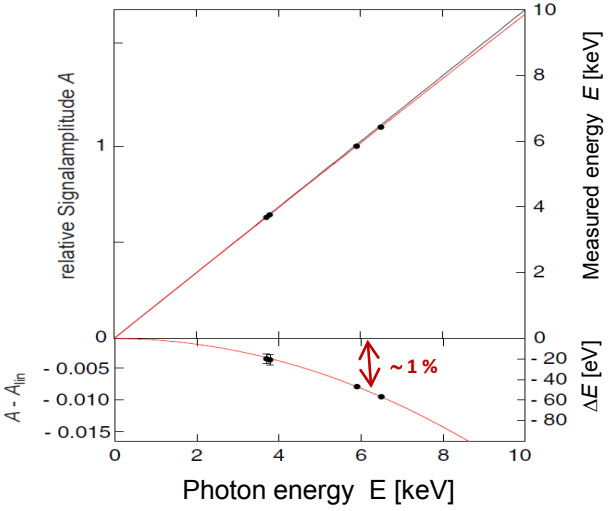
ΔE_{FWHM} = 1.6 eV @ 6 keV



Rise Time: 90 ns



Non-Linearity < 1% @6keV



ECHo experiment: Calorimetric spectrum

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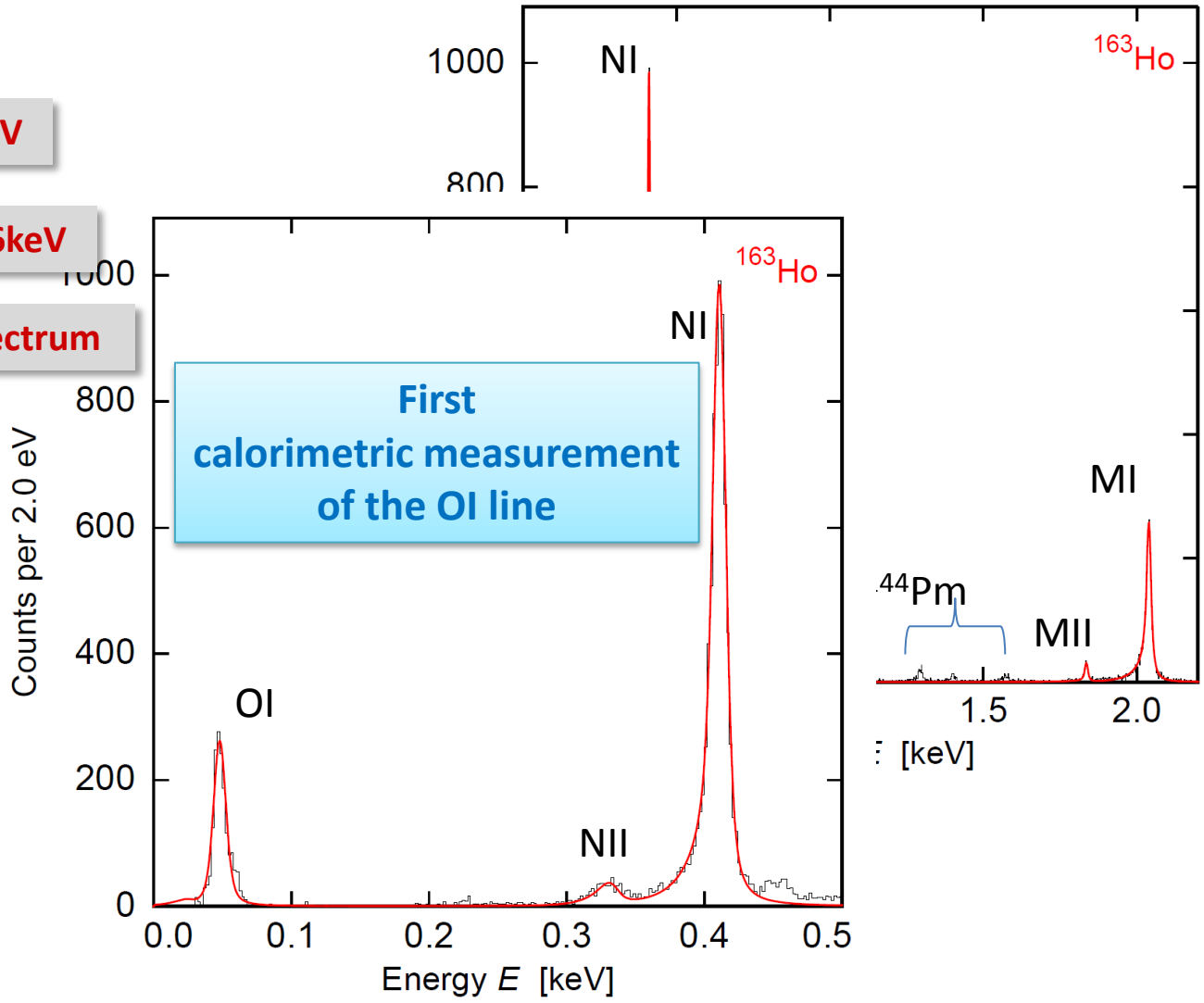

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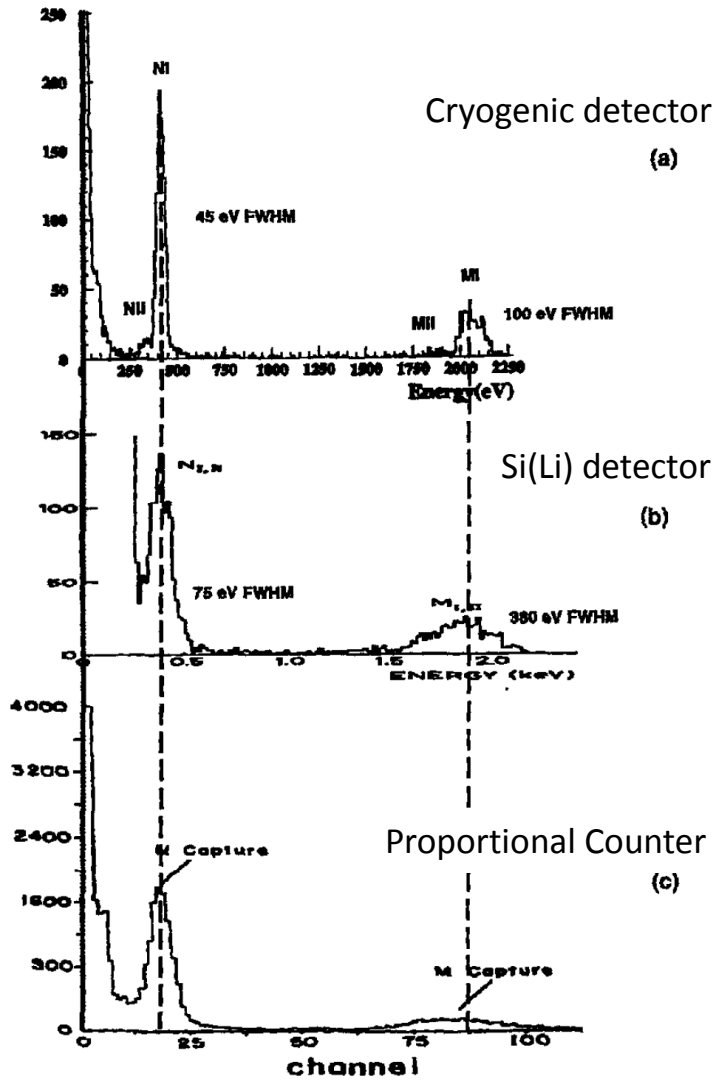
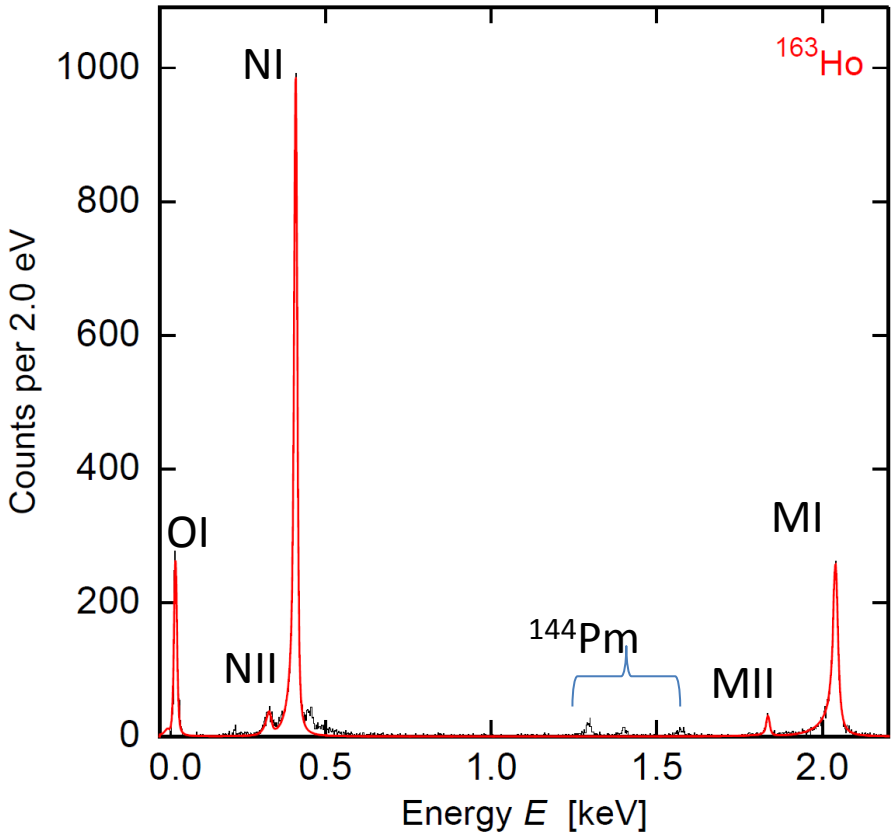


F. Gatti et al., Physics Letters B 398 (1997) 415-419



(a) F. Gatti et al., Physics Letters B 398 (1997) 415-419
(b) E. Laesgaard et al., Proceeding of 7th International Conference on Atomic Masses and Fundamental Constants (AMCO-7), (1984).
(c) F.X. Hartmann and R.A. Naumann, Nucl. Instr. Meth. A 3 13 (1992) 237.