Kirchhoff-Institut for Physics

Neutrino mass determination by high precision measurements of the ^{163}Ho electron capture spectrum

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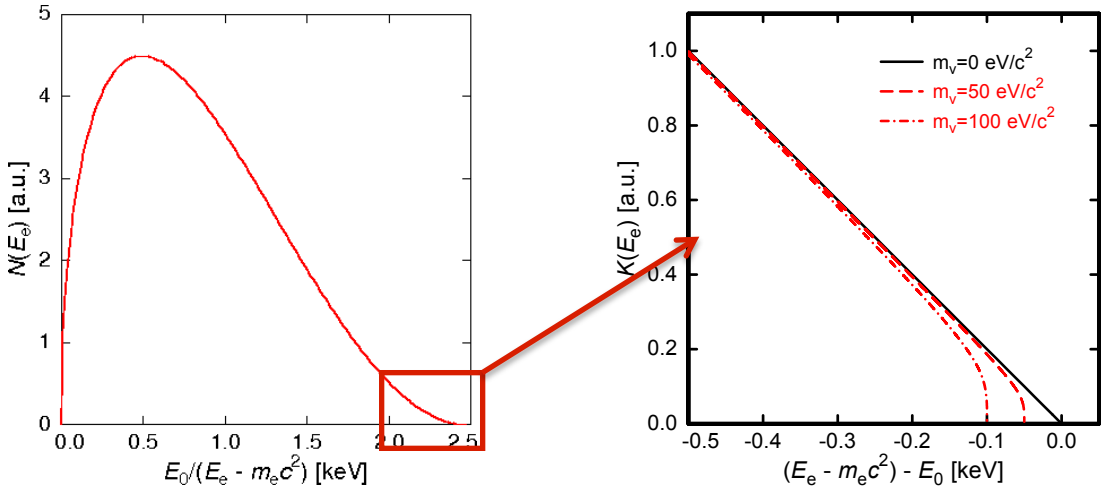
- Direct neutrino mass measurements
- Metallic Magnetic Calorimeter (MMCs)
- The Electron Capture ^{163}Ho Experiment: ECHO
- Conclusions

Direct neutrino mass measurement

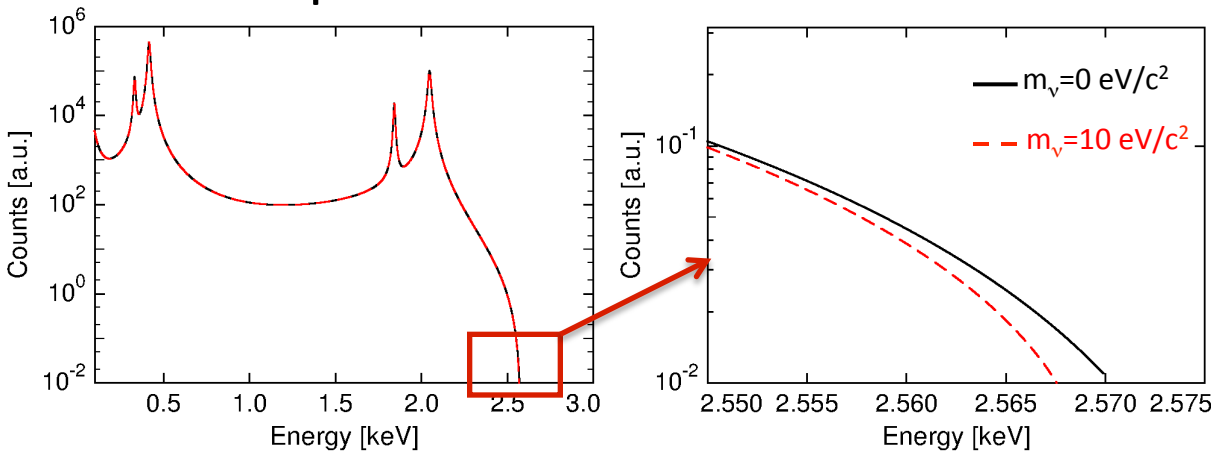
β-decay: ^{187}Re, ^{3}H



$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^{-} + \bar{\nu}_e $$

Electron capture: ^{163}Ho

$$ {}^{A}_{Z}X + e^{-} \rightarrow {}^{A}_{Z-1}Y^{*} + \nu_e $$

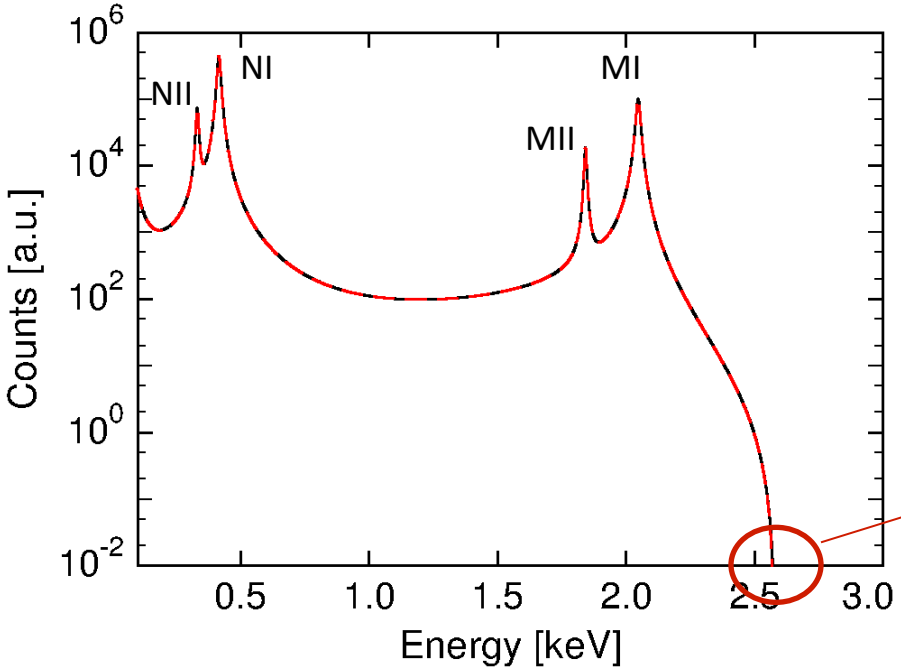


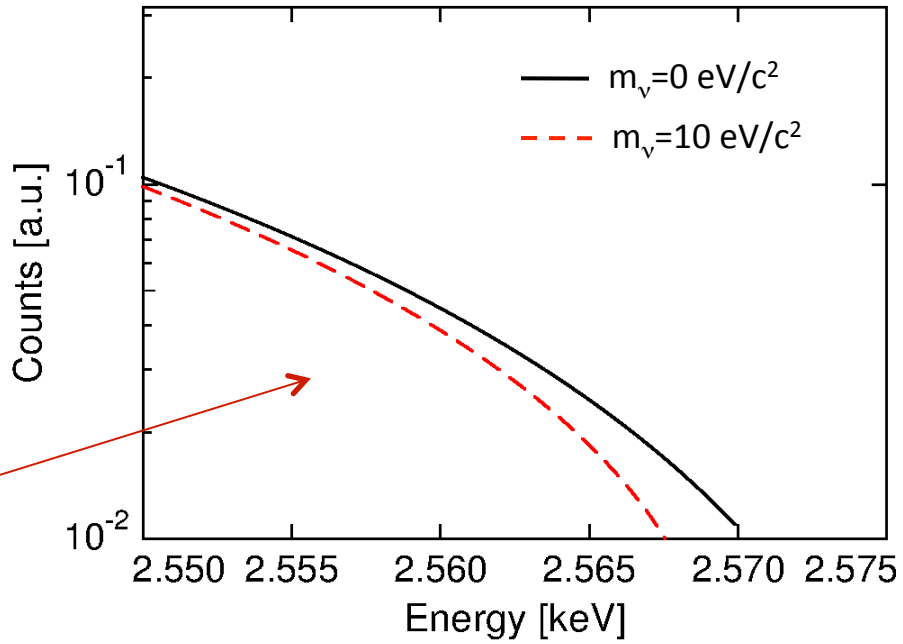
The Case of ^{163}Ho

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

$$^{163}_{66}\mathrm{Dy}^* \rightarrow {}^{163}_{66}\mathrm{Dy} + E_{ph} + E_e$$

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





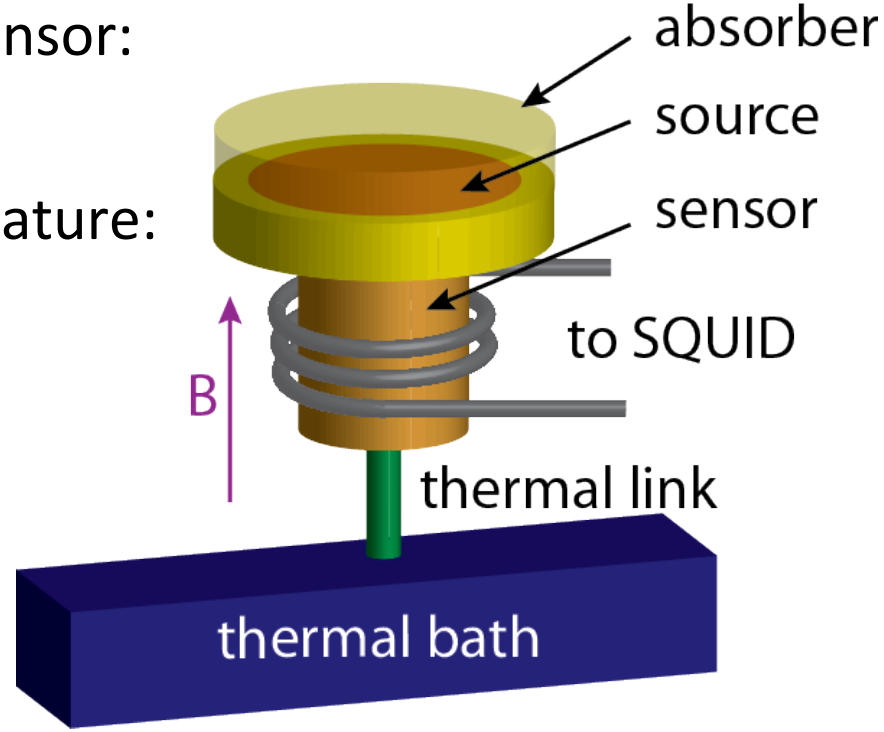
Calorimetric spectrum:

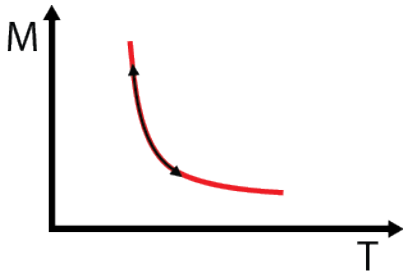
Measuring the energy of all de-excitation channels simultaneously

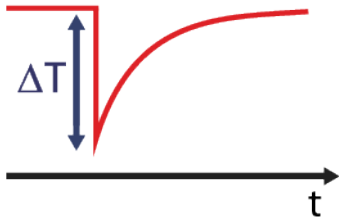
➔ Source contained in the detector

Metallic Magnetic Calorimeters: Concept

- Paramagnetic sensor:
  Au:Er
- Working temperature:
  ~30 mK

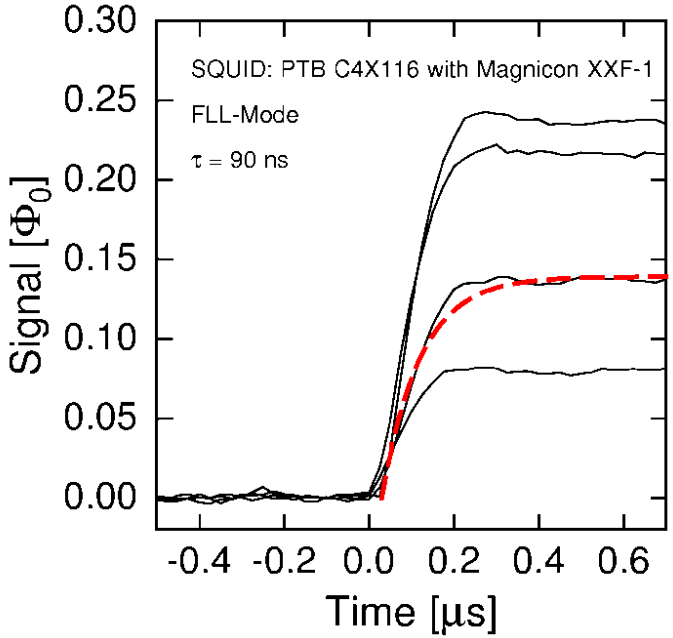






$$\Delta\Phi_S \propto \frac{\partial M}{\partial T}\Delta T \quad \rightarrow \quad \Delta\Phi_S \propto \frac{\partial M}{\partial T}\frac{E}{C_{sens}+C_{abs}}$$

MMCs: Performance

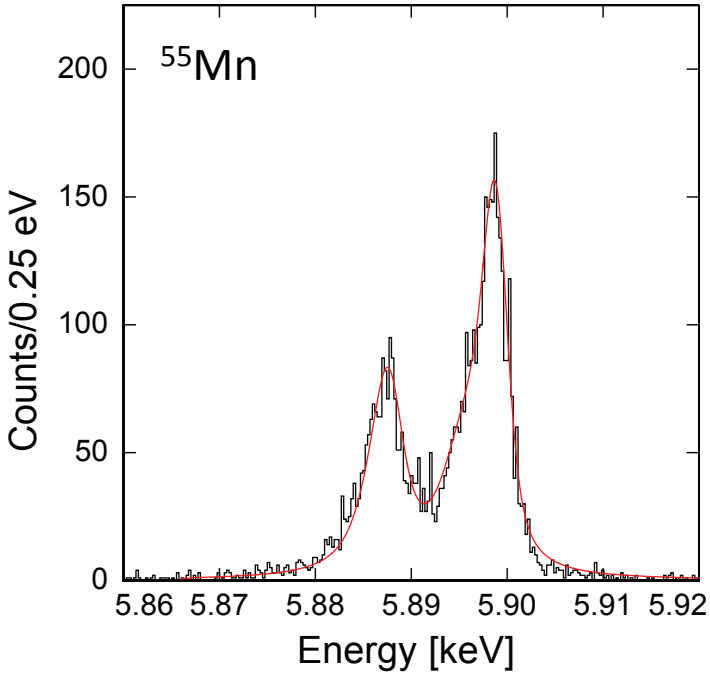


Very fast rise-time

τ_r = 90 ns

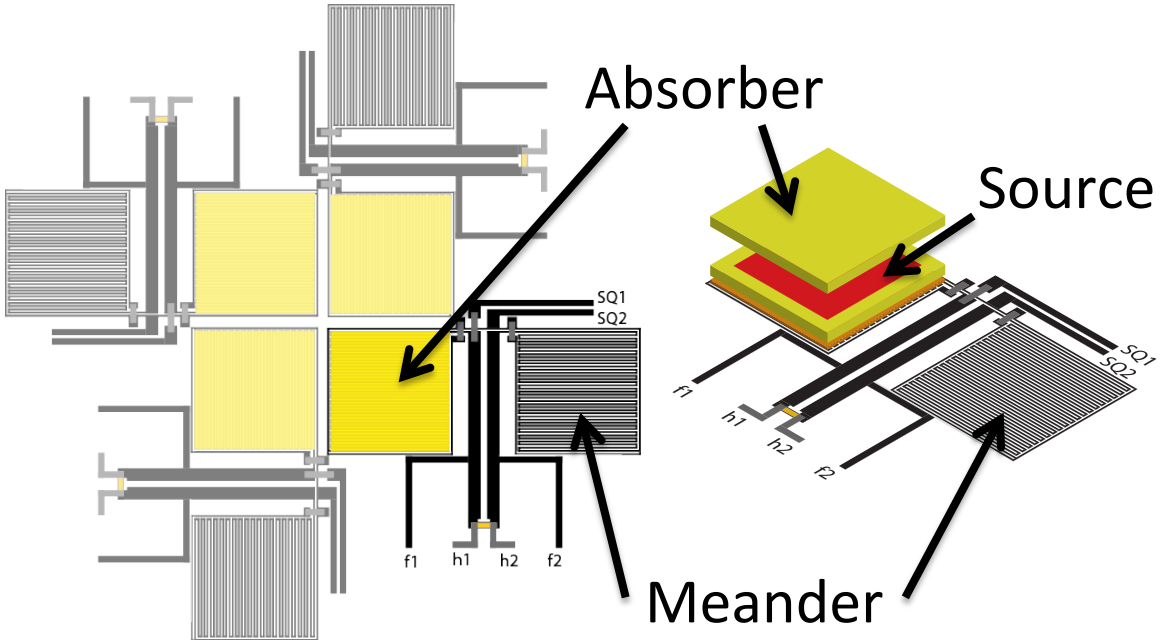
Very good energy resolution

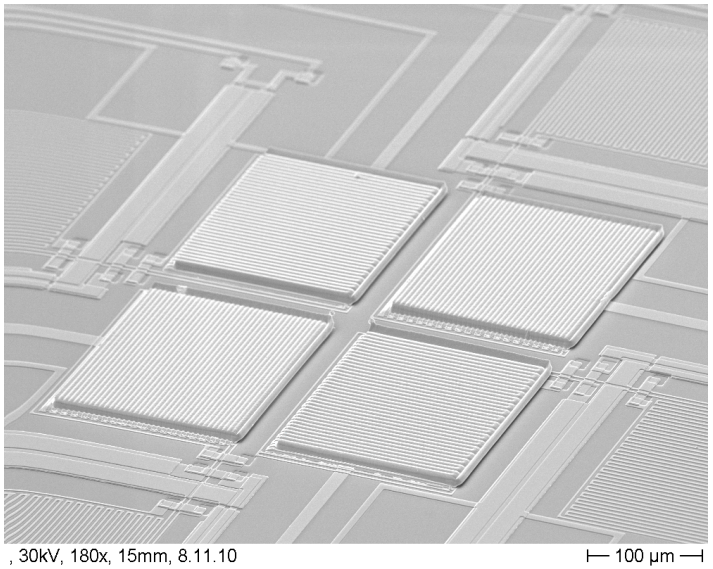
ΔE_{FWHM} = 2.0 eV @ 6 keV



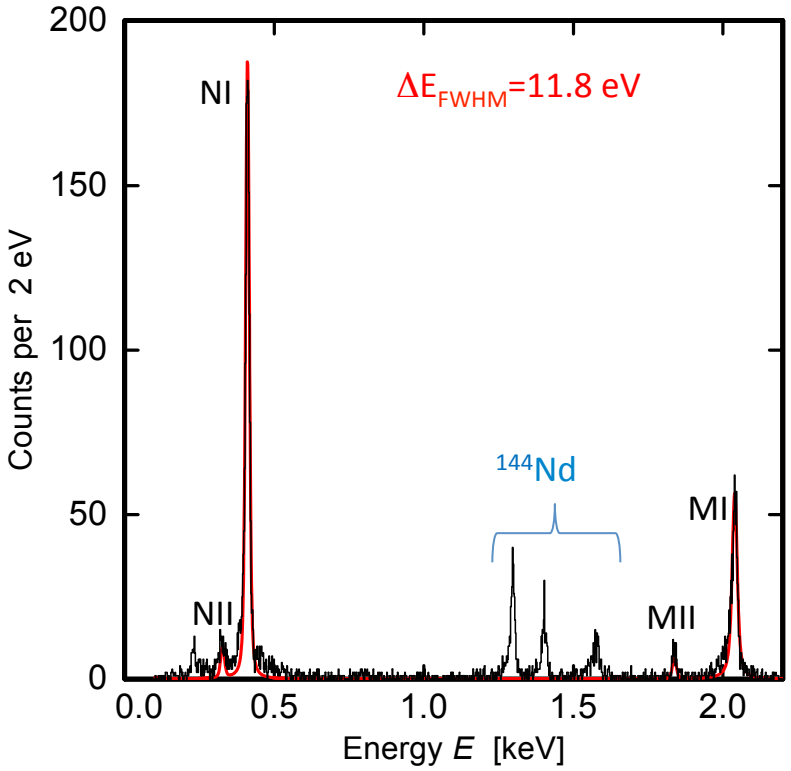
^{163}Ho detector prototype

- Planar meander shaped pick-up coil
- 4 detectors on 5 mm x 5 mm silicon substrate
- Centered 190 µm x 190 µm absorbers for ion implantation at ISOLDE/CERN
- 4π geometry with close to 100 % quantum efficiency



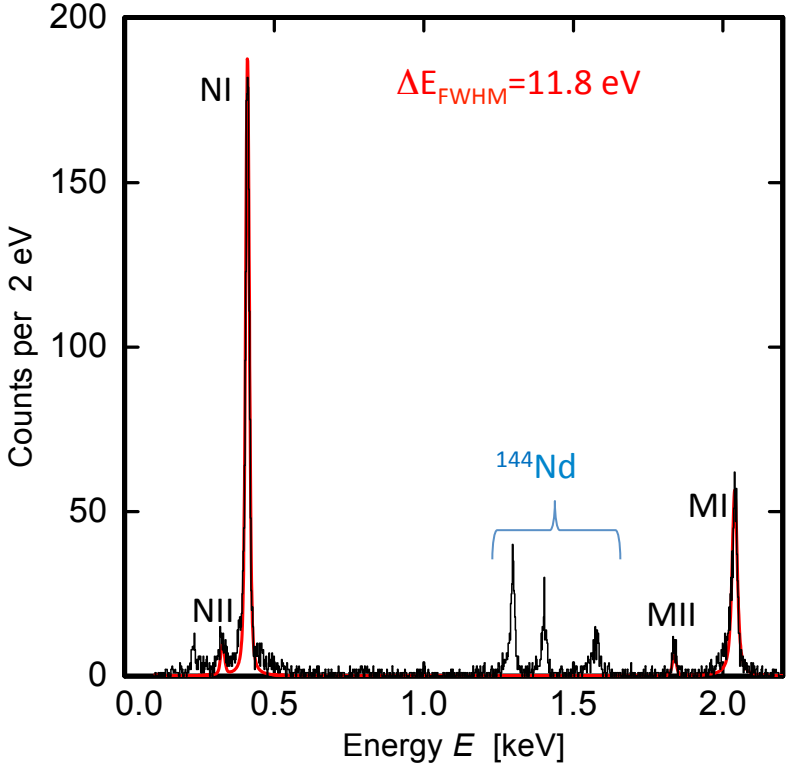


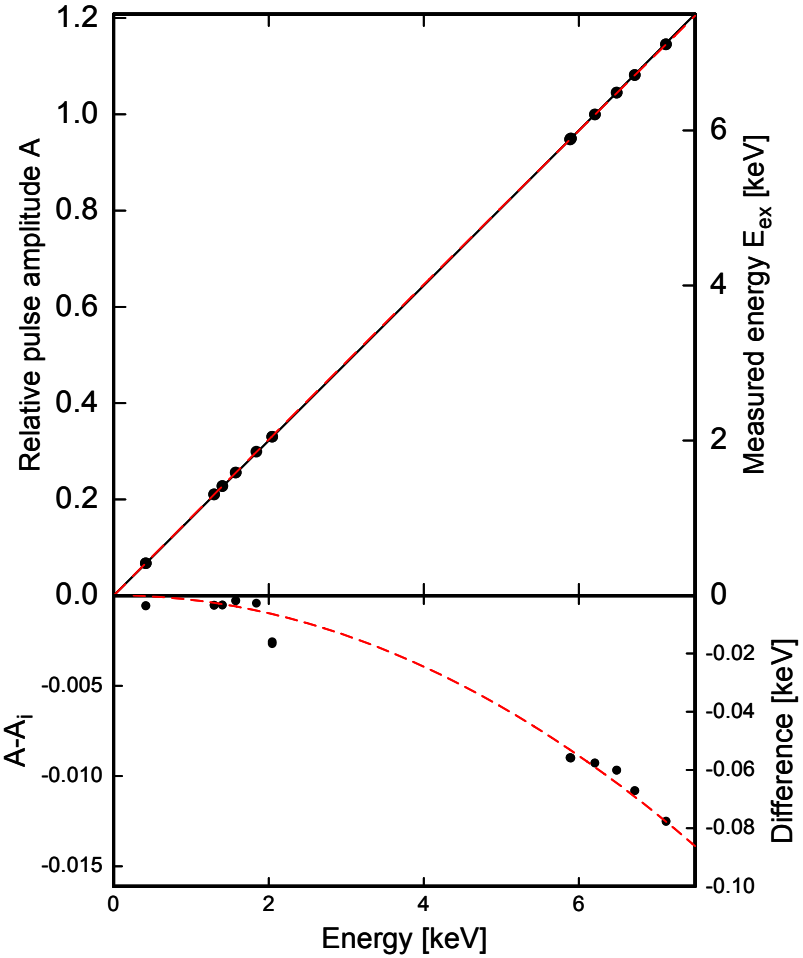
^{163}Ho experiment: Calorimetric spectrum



- Contamination of the beam: presence of ^{147}Gd chain (^{147}Gd→ ^{147}Eu→ ^{147}Sm) and ^{144}Pm→ ^{144}Nd
  - Improvement by collaboration with other groups

^{163}Ho experiment: Calorimetric spectrum



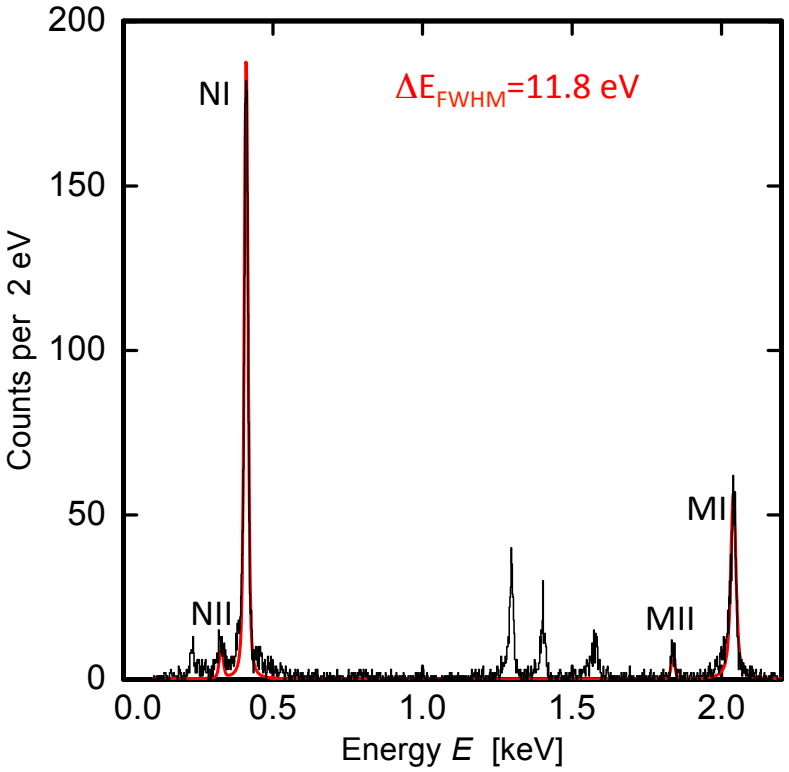


- Best resolved calorimetric ^{163}Ho spectrum to date
  - Aiming for ΔE_{FWHM}<2 eV
- Rise time: τ < 0.1µs
- Good linearity < 5 ‰ at 2.5 keV

^{163}Ho experiment: Calorimetric spectrum

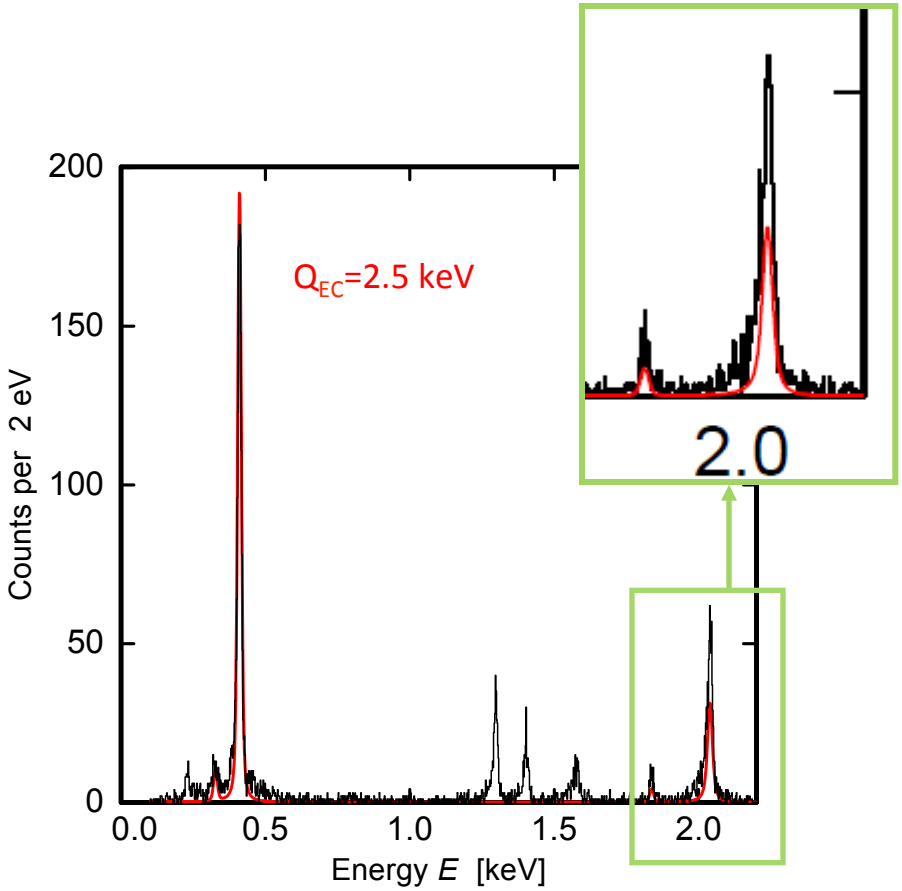
Experimental binding energy values :

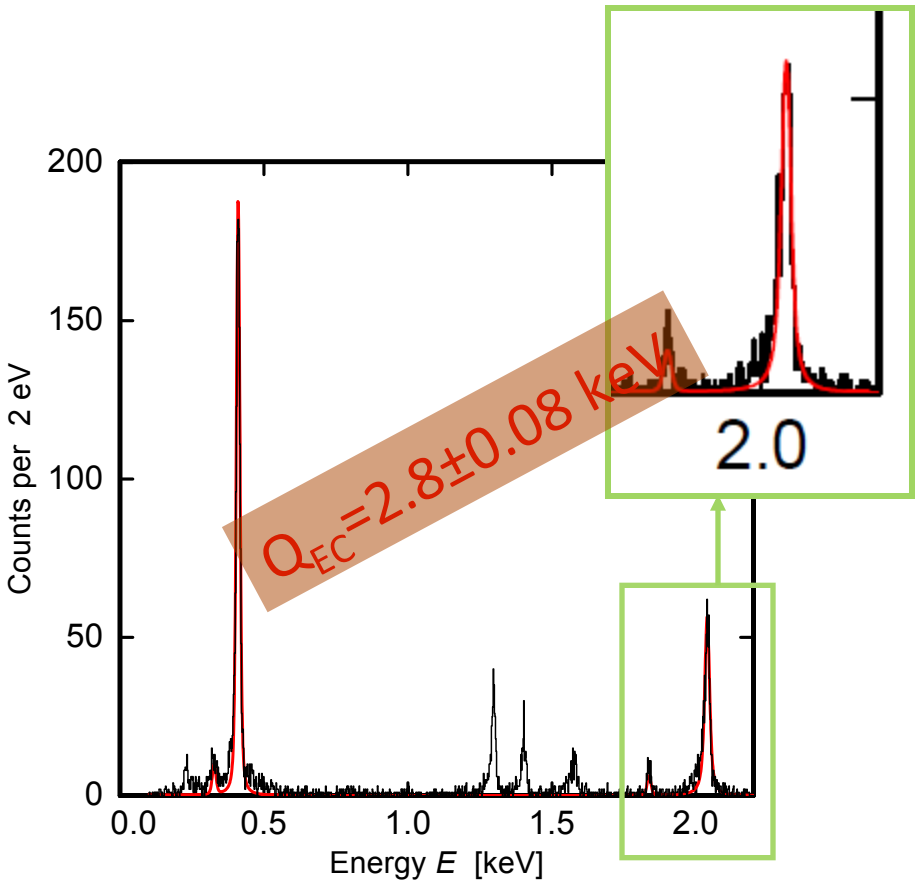
Line	E_{lit} [keV]	E_{exp} [keV] (σ = 5 eV)
MI	2.047	2.042
MII	1.842	1.840
NI	0.416	0.411
NII	0.332	0.325



^{163}Ho experiment: Calorimetric spectrum

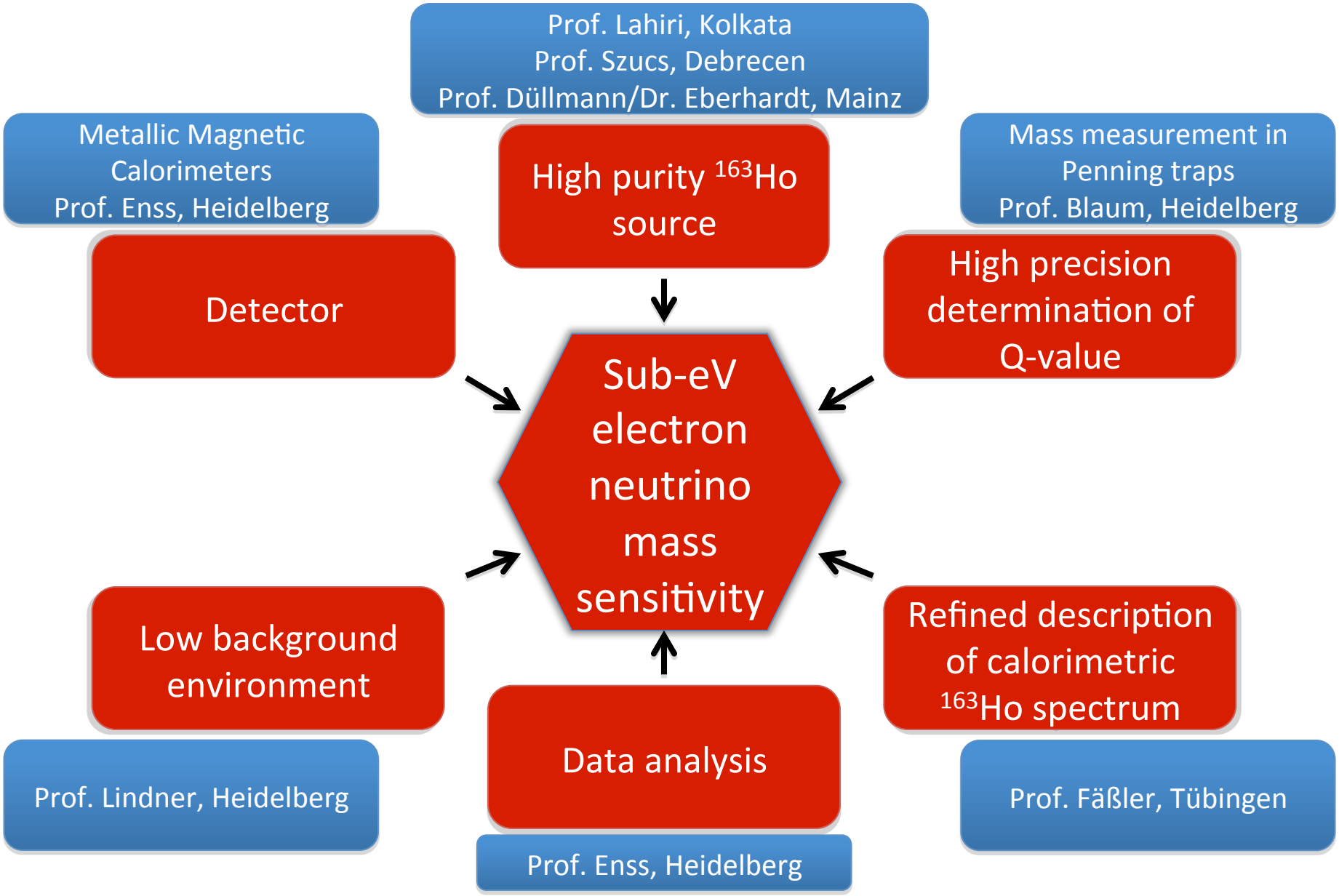
Determination of the Q_{EC} value from the intensity-ratios for m_ν=0:





Independent Q_{EC} measurement necessary ➔ PENTATRAP experiment
by group of Prof. Blaum at MPI-K, Heidelberg
by mass measurement of ^{163}Dy and ^{163}Ho

The Electron Capture ^{163}Ho Experiment: ECHO



Conclusions & Outlook

- Direct neutrino mass measurements
  - ➢ The Electron Capture ^{163}Ho Experiment: ECHO
- Development of MMCs for high precision measurements of the calorimetric spectrum of ^{163}Ho
- First Detector with implanted ^{163}Ho shows promising results
  - ➢ Ongoing detector optimization
- From single pixel to arrays
  - ➢ Microwave multiplexing

Thank you!

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Susanta Lahiri

Falk von Seggern

Sebastian Kempf

Simon Uhl

Karl Johnston

Christian Enss

Yuri Novikov

Zoltan Szucs

Christoph Düllmann

Thomas Wolf

Moumita Maiti

Klaus Blaum

Daniel Hengstler

Lisa Gamer

Alexander Herlert

Sergey Eliseev

Nadine Foerster

Jeshua Geist

Klaus Eberhardt

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