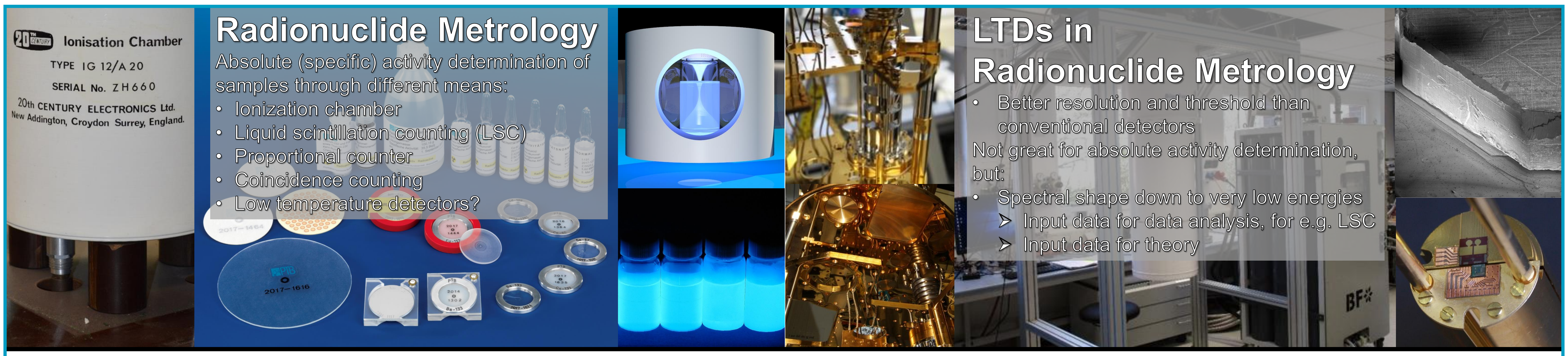
Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

MetroMMC: Electron-capture spectrometry with cryogenic calorimeters for science and technology

P. C.-O. Ranitzsch[1], D. Arnold[1], J. Beyer[2], L. Bockhorn[1,3], J. J. Bonaparte[4,5], C. Enss[5], K. Kossert[1], S. Kempf[5], M. Loidl[6], R. Mariam[6], O. J. Nähle[1], M. Paulsen[2,5], M. Rodrigues[6], M. Wegner[5]

[1]PTB Braunschweig, Germany, [2]PTB Berlin, Germany, [3]Institut für Festkörperphysik, Leibniz Universität Hannover, Germany, [4]Comision Nacional de Energia Atomica, Buenos Aires, Argentina, [5]Kirchhoff-Institute für Physik, Universität Heidelberg, Germany, [6]CEA, List, Laboratoire National Henri Bequerel, CEA-Saclay, France



Radionuclide Metrology

Absolute (specific) activity determination of samples through different means:

- Ionization chamber
- Liquid scintillation counting (LSC)
- Proportional counter
- Coincidence counting
- Low temperature detectors?

LTDs in Radionuclide Metrology

- Better resolution and threshold than conventional detectors

Not great for absolute activity determination, but:

- Spectral shape down to very low energies
  - ➢ Input data for data analysis, for e.g. LSC
  - ➢ Input data for theory

Project partners:

PTB, cea, Universität Heidelberg, NPL, cnrs, FCT Faculdade de Ciências e Tecnologia Universidade Nova de Lisboa, KRISS

MetroMMC

Measurement of fundamental nuclear decay data using Metallic Magnetic Calorimeters

Project goals:

Electron capture spectrometry:

- Calorimetric 4π-measurements
- X-ray emission measurements
- Theoretical description

Nuclides:
^{41}Ca, ^{54}Mn, ^{59}Ni, ^{65}Zn, ^{109}Cd, ^{125}I

X-ray emission from electron capture

X-ray source
- Circular electroplated source
- Primary / traceable activity determination

Detector shield
Shield against non-radiative transitions (mostly electrons)
- Beryllium window
- Magnetic deflection

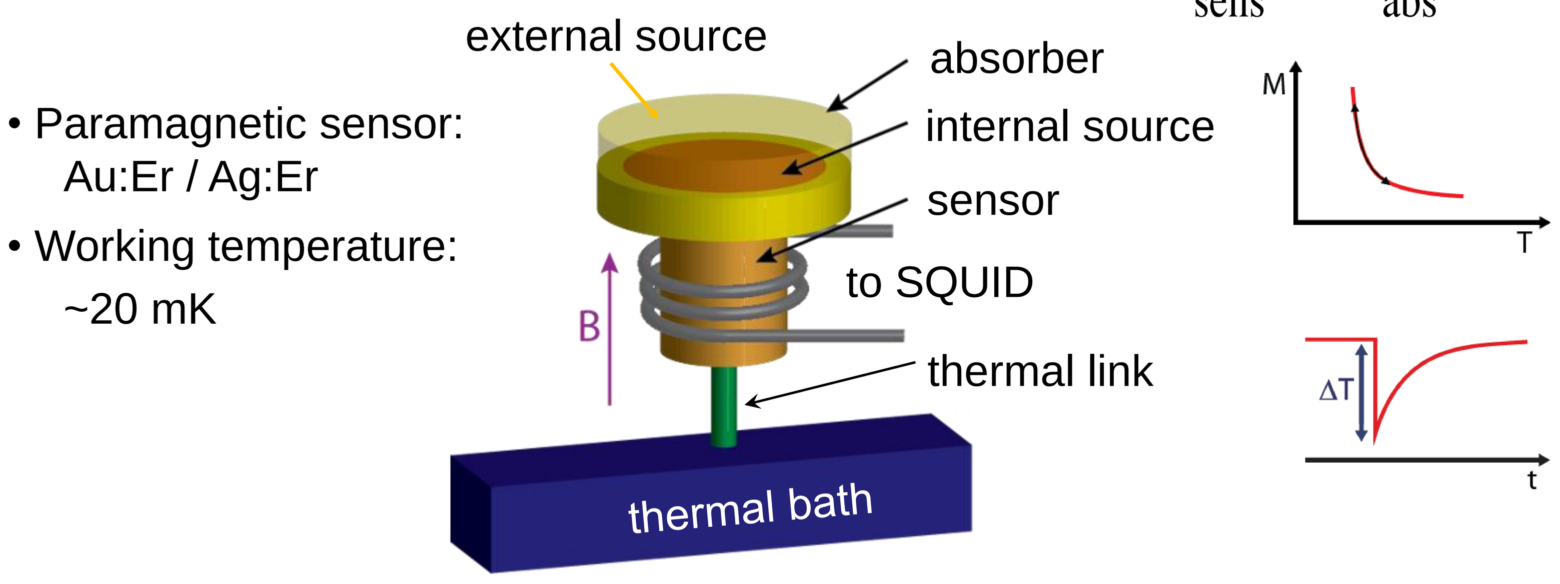
Collimator
- Define geometric efficiency
- Calibrate geometry e.g. with α-source

Detection efficiency
- Monte-Carlo simulation
- Experimentally with well characterized sources

Metallic magnetic calorimeters (MMCs)

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

- Paramagnetic sensor: Au:Er / Ag:Er
- Working temperature: ~20 mK



Full spectrum from electron capture decay

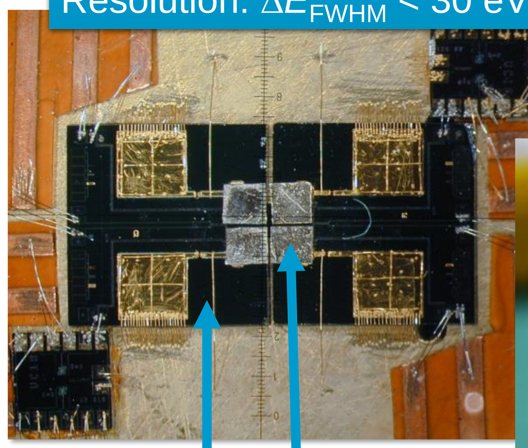
Radionuclide source
- Embedded in absorber material
- Absorption efficiency > 99.99 %
- Usually build separate from detector chip
- Heat capacity matched to designated detector design
- Preparation: Poster 208-125

Energy calibration
- External X-ray / γ source
- Sometimes optional

Detector systems:

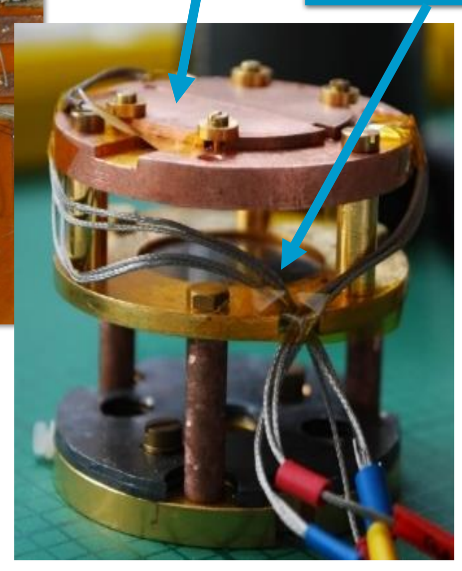
SMX3
Established detector
Energy range: 5…26 keV
Resolution: ΔE_{FWHM} < 30 eV

Chip holder with
- Be-window
- collimator



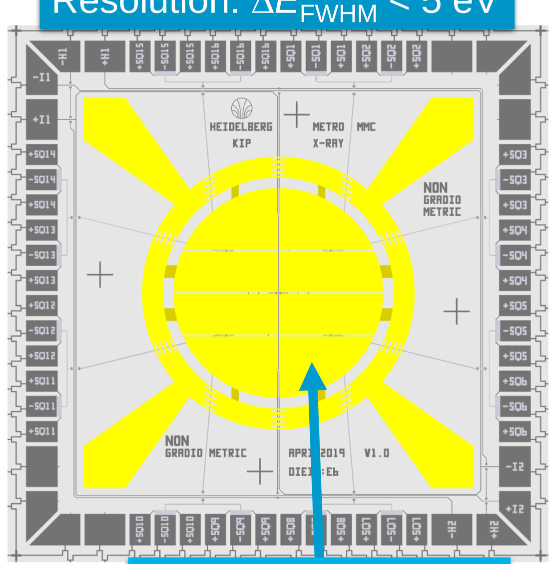
2 x 2-pixel MMC-chips

1 x 1 mm²
Au(50 µm)-Ag(17 µm) bilayer absorber



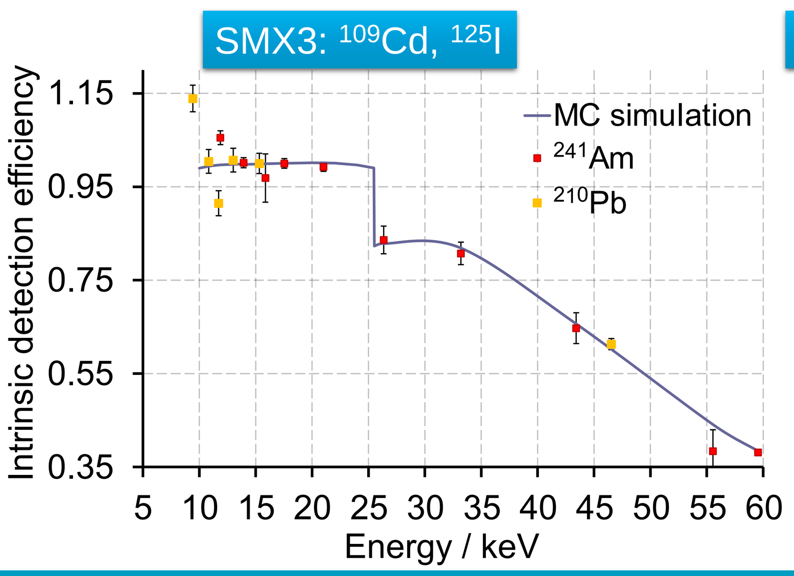
Radionuclide source

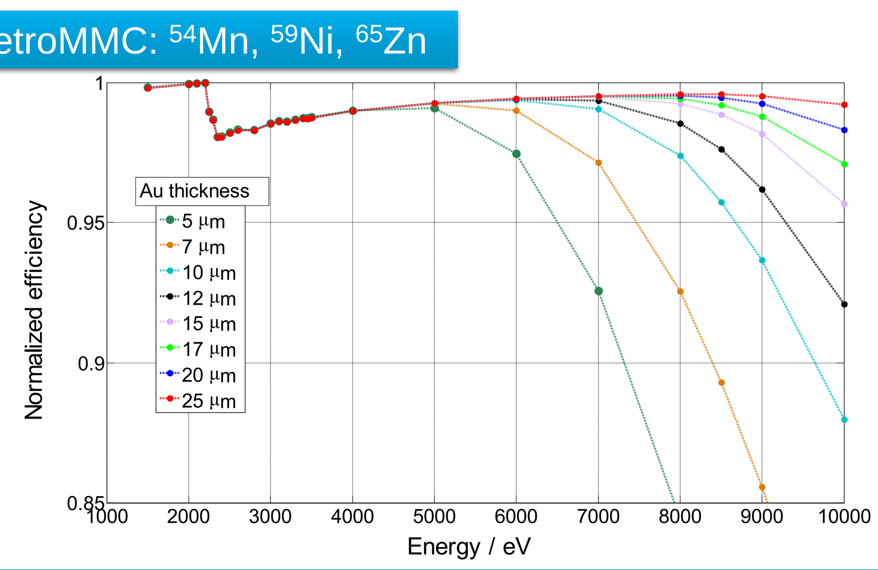
MetroMMC X-ray
New design
Energy range: < 10 keV
Resolution: ΔE_{FWHM} < 5 eV



(8 x 0.375) mm²
Au (17 µm) absorber

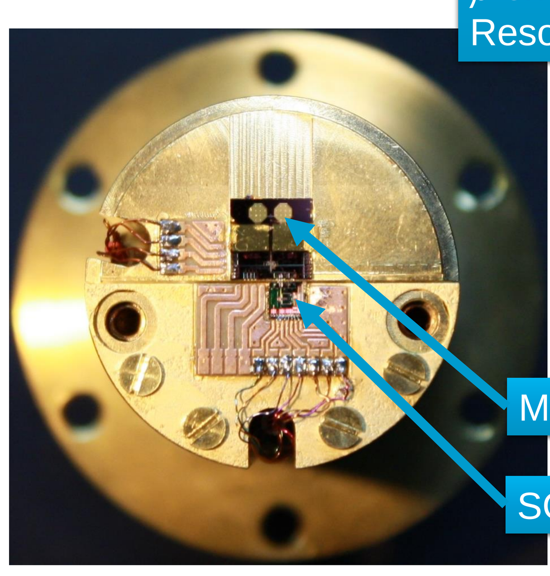
Detection efficiency:



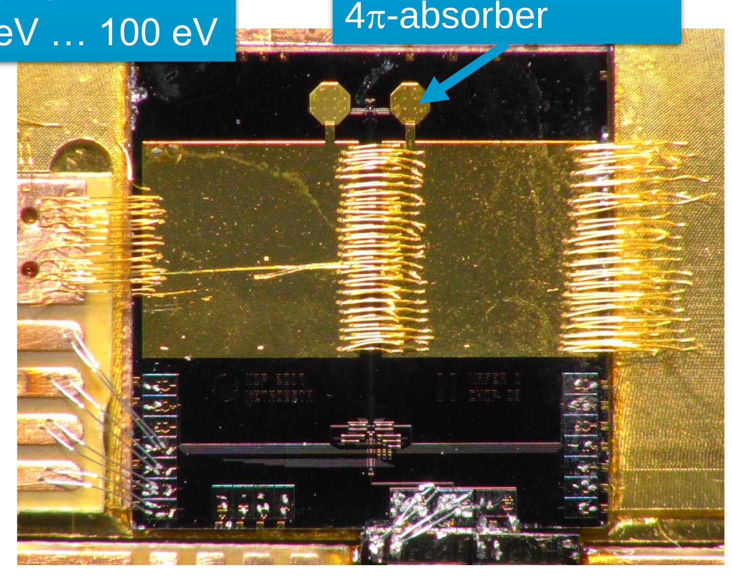


Detector systems:

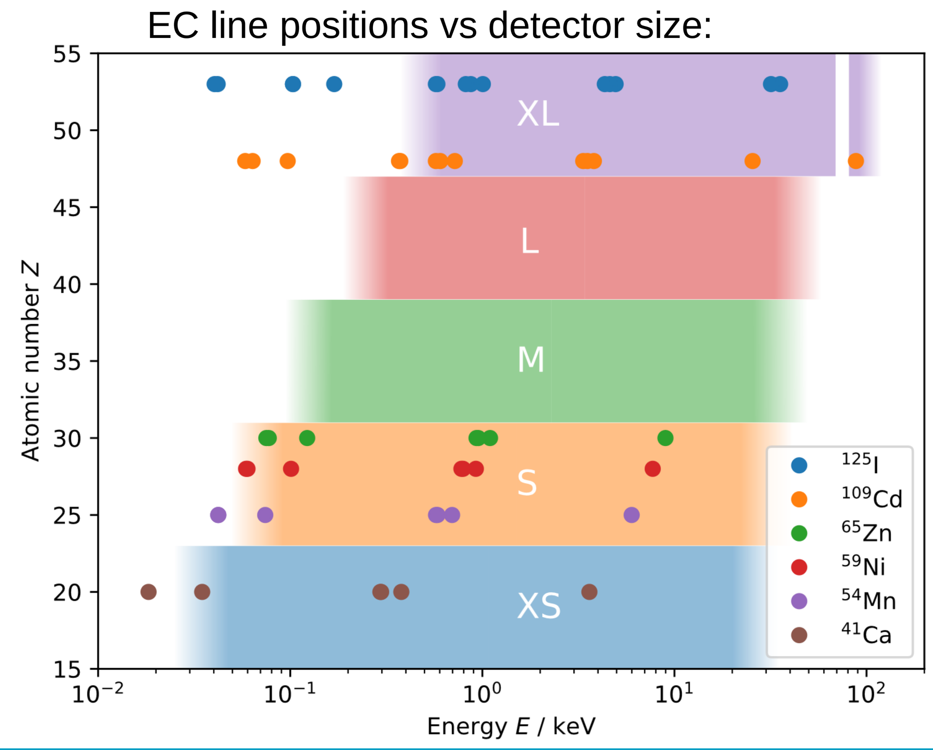
MetroBeta MMC
Five sizes: XS … XL
β-endpoint: 70 keV … 700 keV
Resolution: ΔE_{FWHM} < 10 eV … 100 eV



Size M:
2 pixels ready for 4π-absorber



Planned measurements:



Nuclide	E_{max} type	E_{max} / keV	Absorber thickness / µm	Det. size
^{41}Ca	X-ray	3.6028	3	XS
^{54}Mn	X-ray	5.987	8	XS
^{59}Ni	X-ray	7.706	20	S
^{65}Zn (low E)	X-ray	8.9771	25	S
^{65}Zn (high E)	β^+	329.0	70	M
^{109}Cd (low E)	X-ray	25.512	100	M
^{109}Cd (high E)	γ	88.0336	500	XL
^{125}I	γ	35.4922	210	L