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Cryogenic Microcalorimeters

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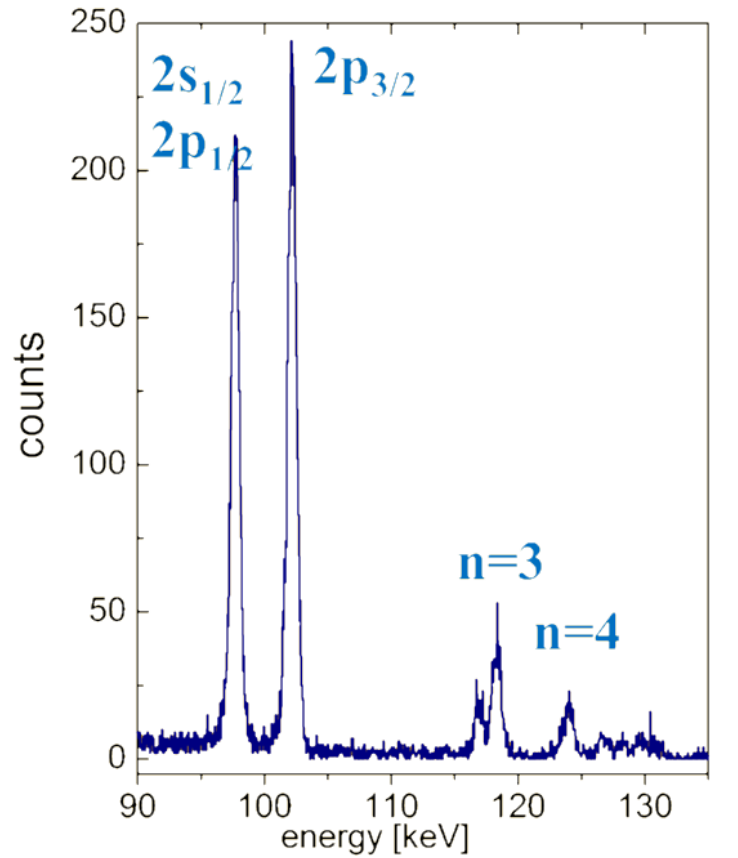
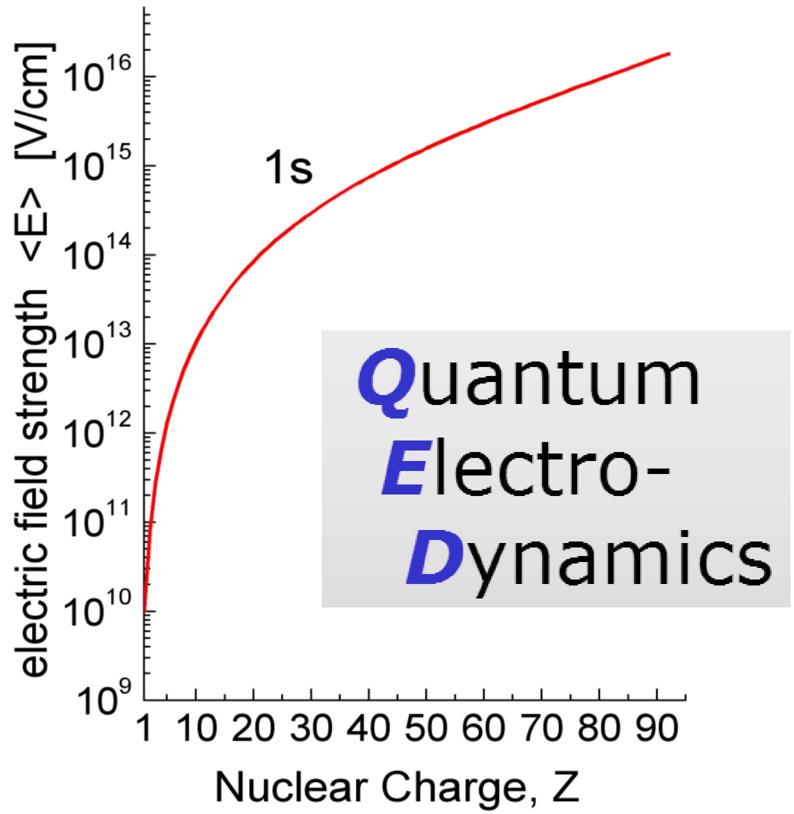
Structural properties of exotic, heavy ions

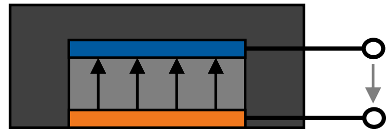




Explore QED, the most precise theory

- in the non-perturbative regime
- not well-known up to now!

What is the Motivation?



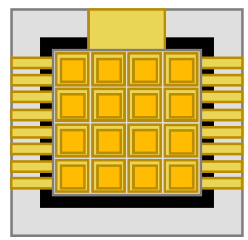
Semiconductor detector

High efficiency
Broad spectral range

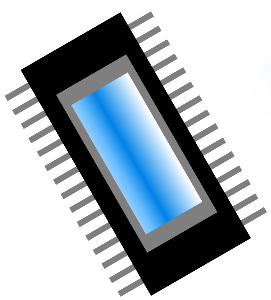
X-Ray Spectroscopy

CCD-Modules

Large dynamic range
Good spatial resolution

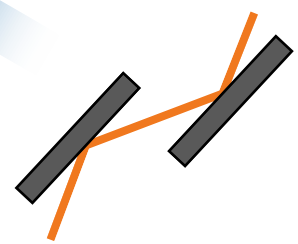


Microcalorimeter



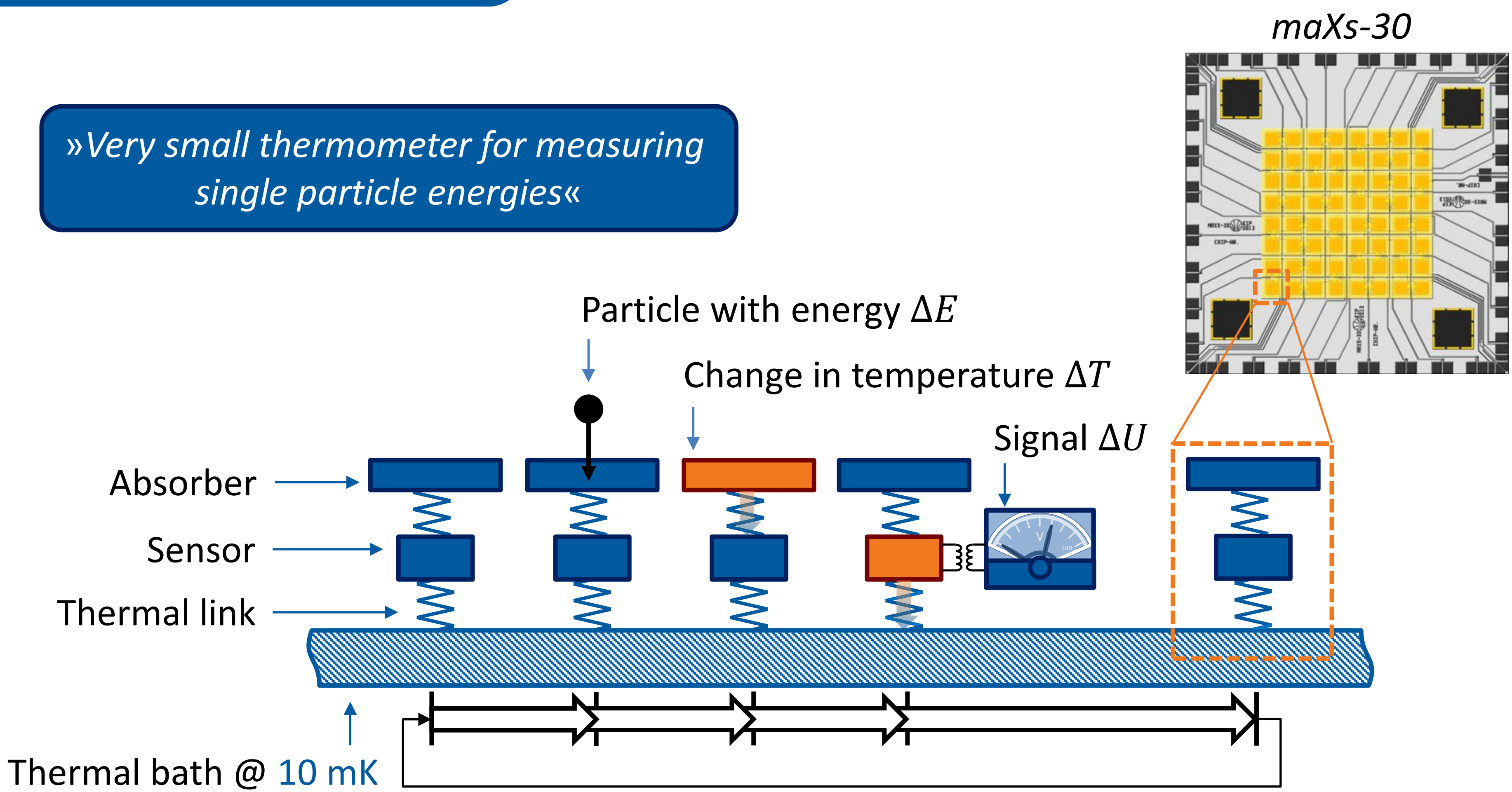
Crystal spectrometer

High energy resolution
High photonflux



What are Microcalorimeters?

»Very small thermometer for measuring single particle energies«

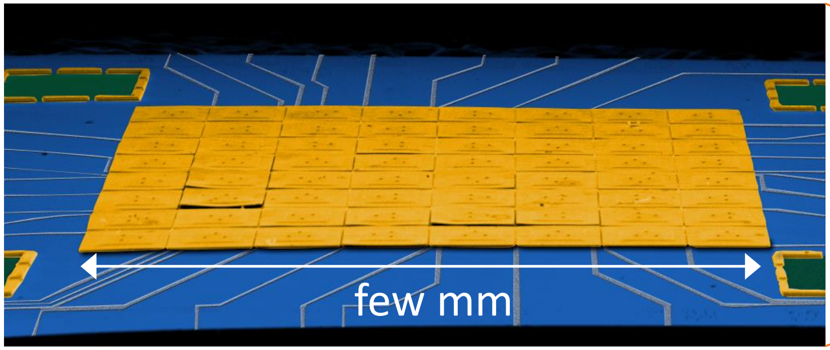


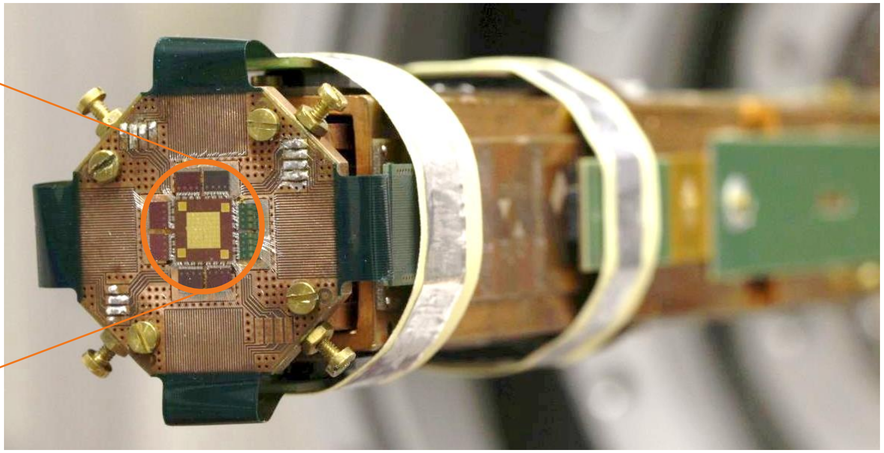
X-Ray Spectroscopy with Microcalorimeters

Excitation energy of phonons is about 1 meV (w_{phonon}).
Excitation energy of electron-hole pairs is about 3 eV ($w_{electron}$).

$$\frac{\Delta E_{calorimeter}}{\Delta E_{semiconductor}} = \sqrt{\frac{N_{electron}}{N_{phonon}}} = \sqrt{\frac{E}{w_{electron}} \cdot \frac{w_{phonon}}{E}} \approx \sqrt{\frac{10^{-3}}{3}} \approx 1/50$$

Huge boost in resolution, but size/volume of the absorbers needs to be quite small.





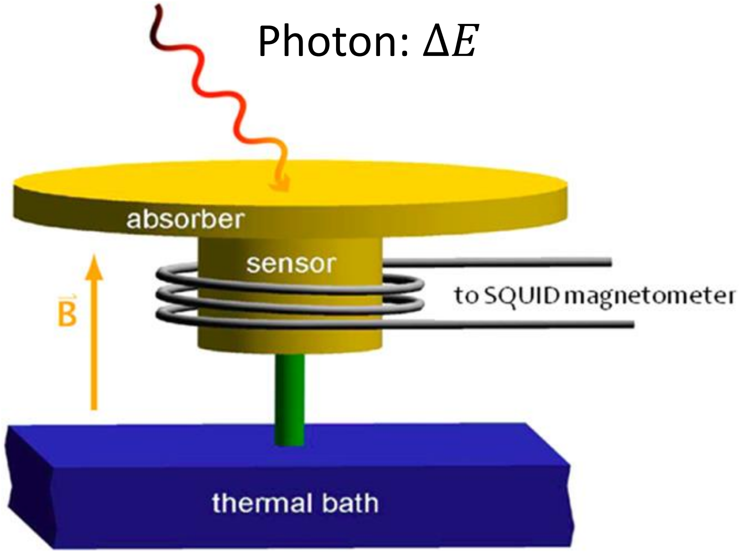
- 8 × 8 absorbers for photons up to 30 keV
- each 0.5mm × 0.5 mm
- 15-30 μm thick gold

MMC: Metallic Magneticcalorimeter

Developed by the group of C. Enss and A. Fleischmann in Heidelberg:

maXs: <u>m</u>icrocalorimeter <u>a</u>rrays for high-resolution <u>X</u>-ray <u>s</u>pectroscopy at GSI/FAIR

Photon: ΔE

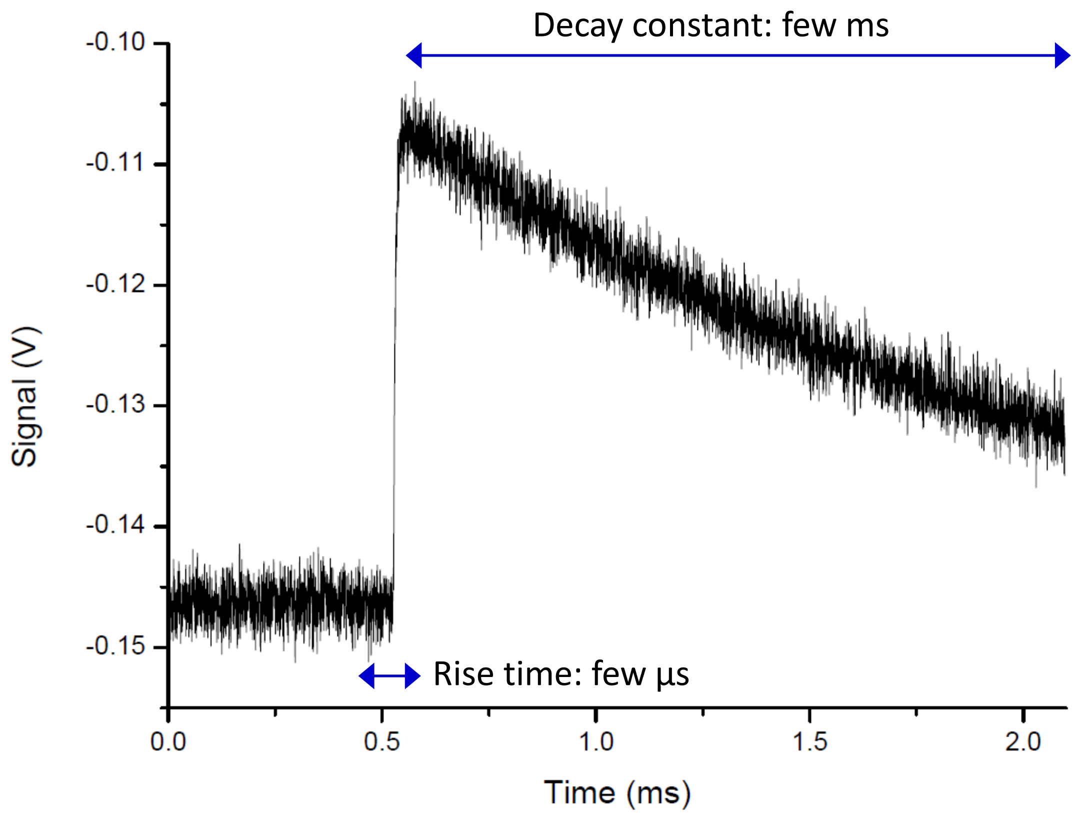


Signal: $\Delta M \rightarrow \Delta\Phi$

$$\Delta T = C \cdot \Delta E \rightarrow \Delta M = \frac{dM}{dT}\Delta T$$

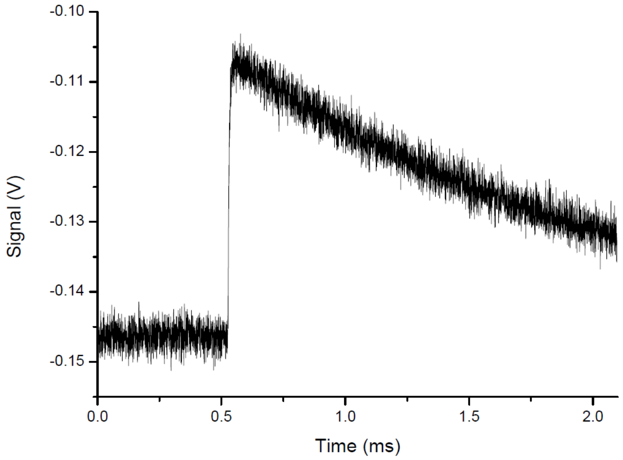
$$\rightarrow \Delta M \propto \Delta E$$

maXs-100: 50 eV FWHM @ 60 keV



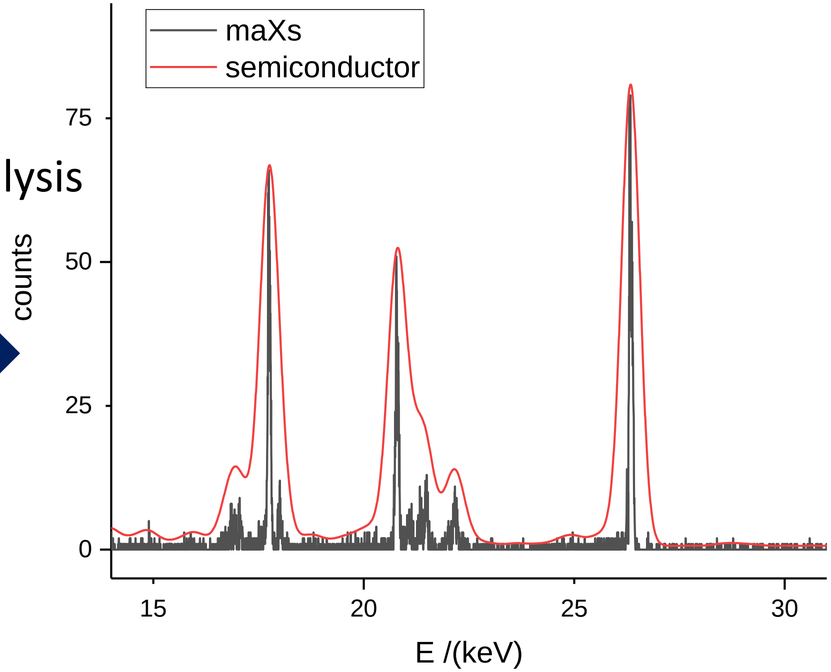
Analysis of maXs Data

Digitized Detector Signal



Pulse Shape Analysis

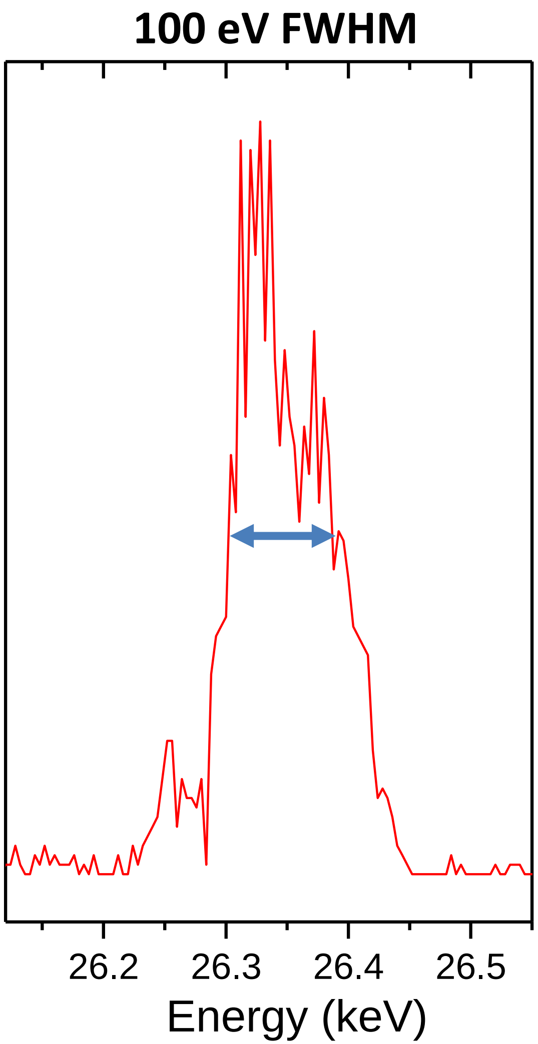
High Resolution Spectrum



Detector response to incident radiation is not stable over time, due to temperature fluctuations.

We have to correct for this effect.

Analysis of maXs Data



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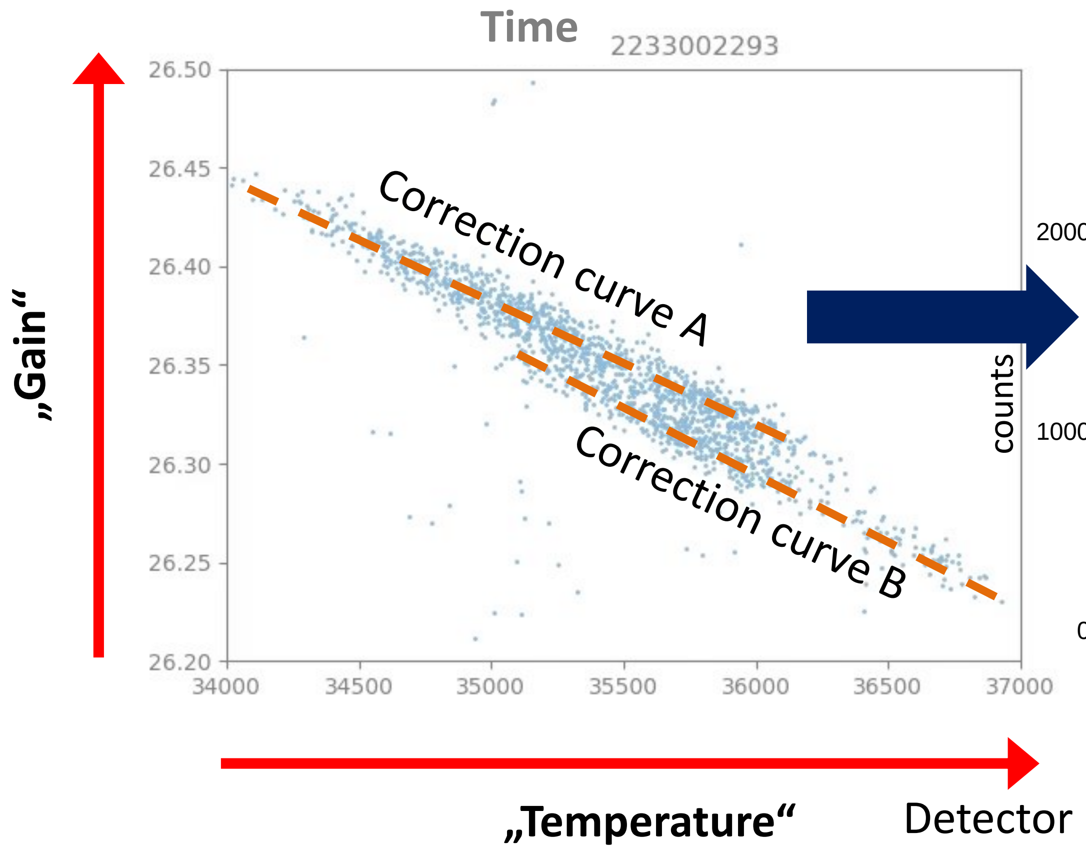

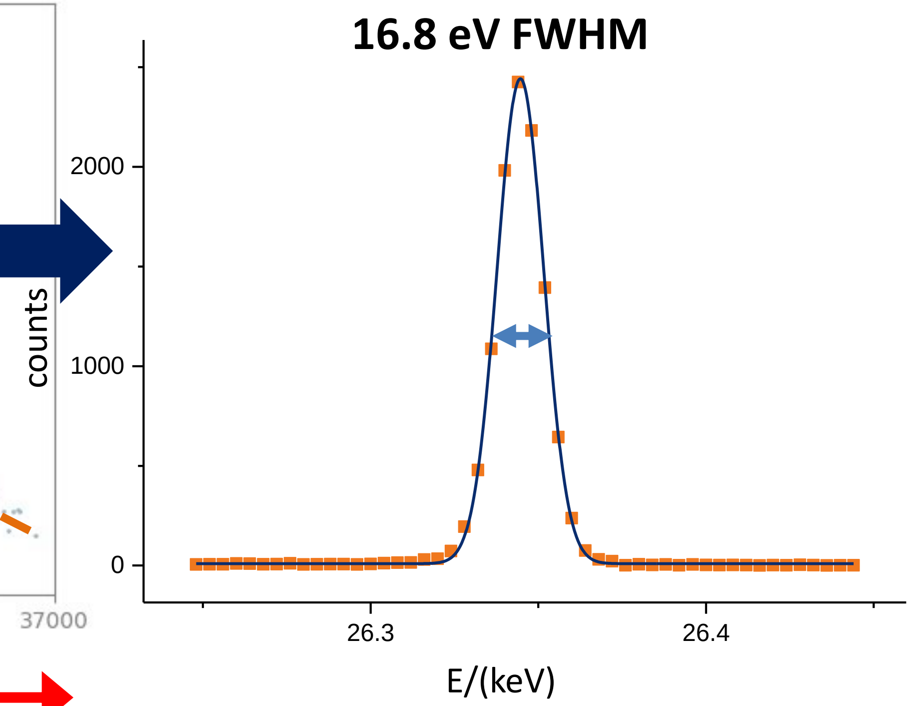

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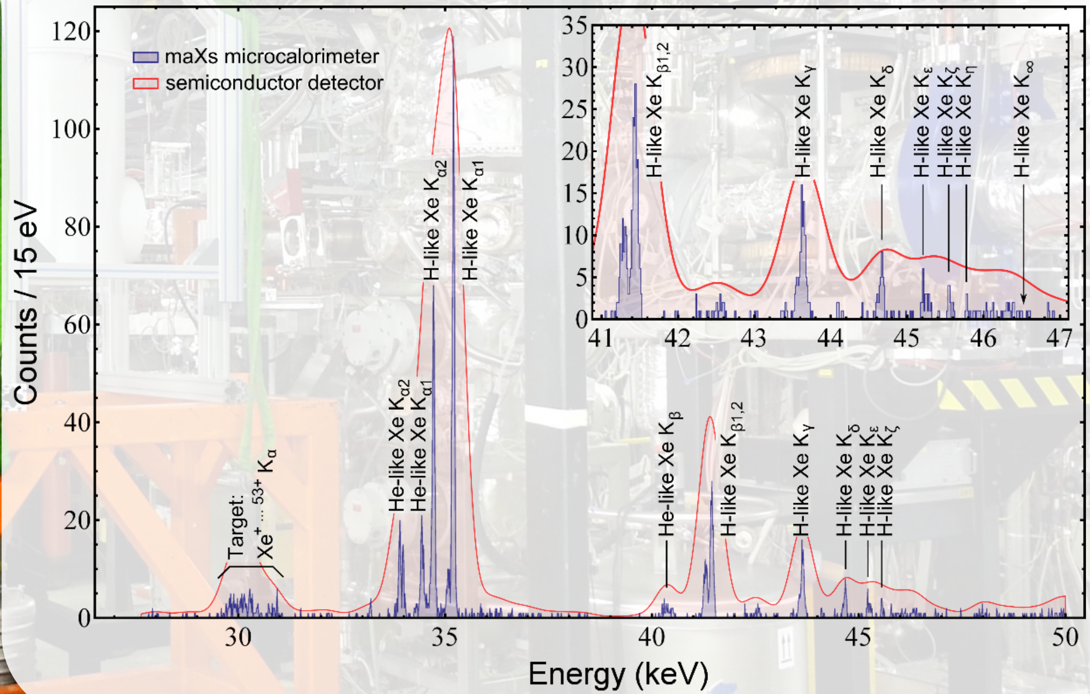
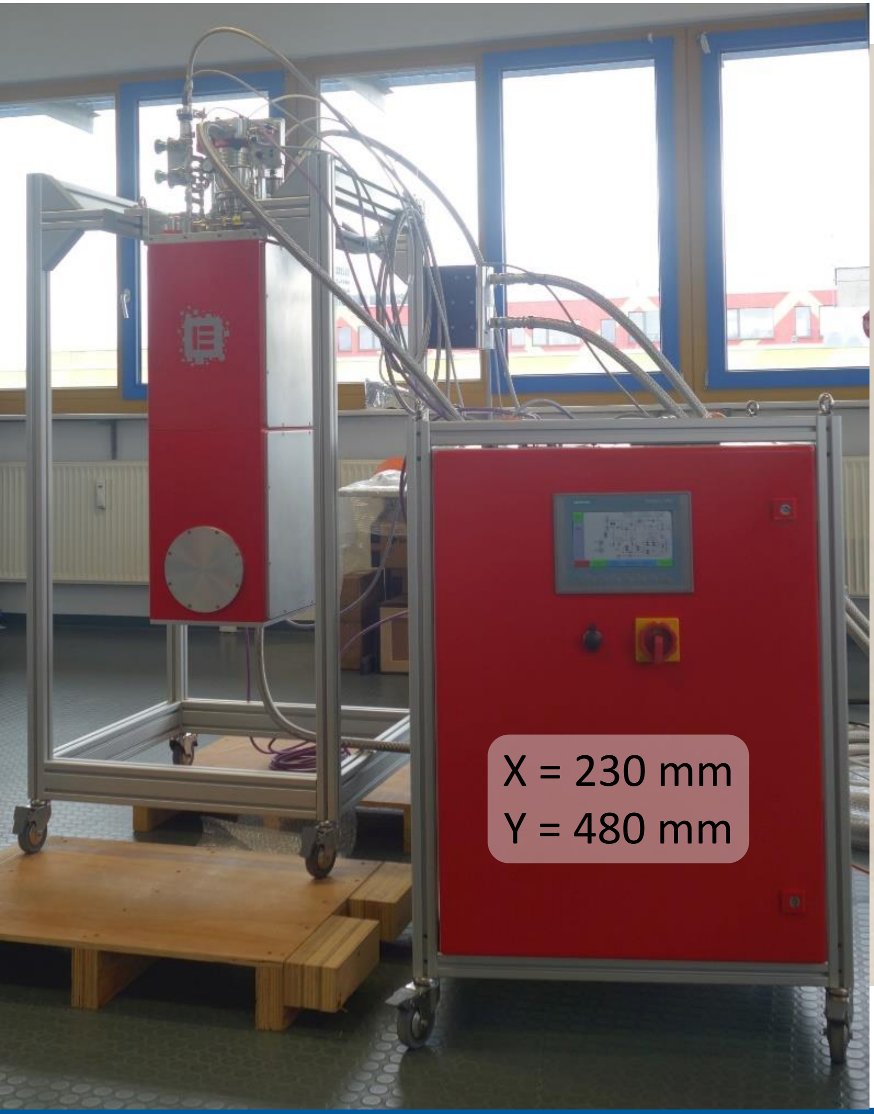
We have to correct for this effect.

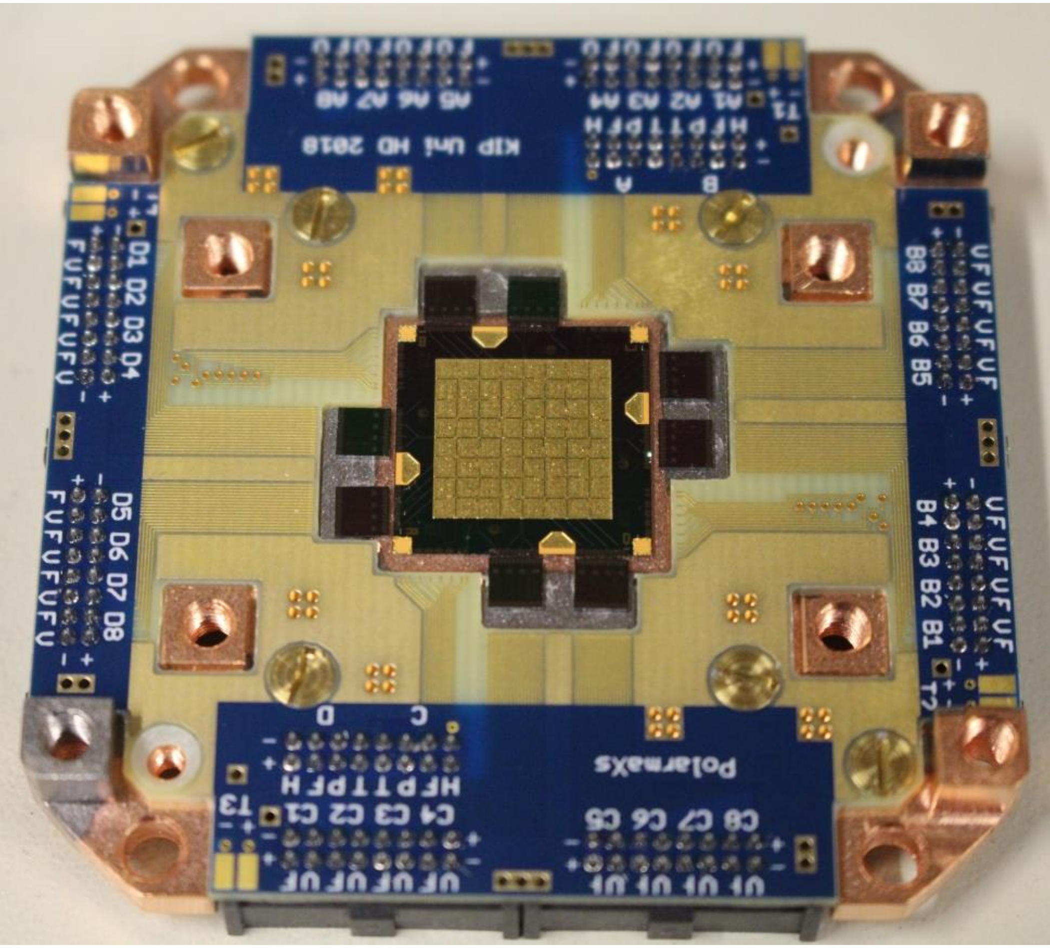
X = 1100 mm
Y = 820 mm

Xe^{54+} => Xe; 50 MeV/u



Current Status





Outlook

- upcoming experiment: 1s Lamb shift in U^{91+}
  - integration of data readout
  - transfer into the heterogenous detector environment of an experiment
- further detector development
  - thicker absorbers
  - more pixels
    therefore multiplexed readout

Credits

Microcalorimeter Development

- A. Fleischmann
- D. Hengstler
- S. Allgeier
- M. Friedrich
- P. Kuntz
- C. Enss

Kirchhoff-Institute for Physics
Heidelberg University

Preparation of Lamb Shift Study

- M. O. Herdrich
- F. Kröger
- B. Zhu
- T. Over
- G. Weber
- Th. Stöhlker

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