Implantation of the ^{163}Ho Source for the ECHo Experiment

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HIM HELMHOLTZ Helmholtz-Institut Mainz

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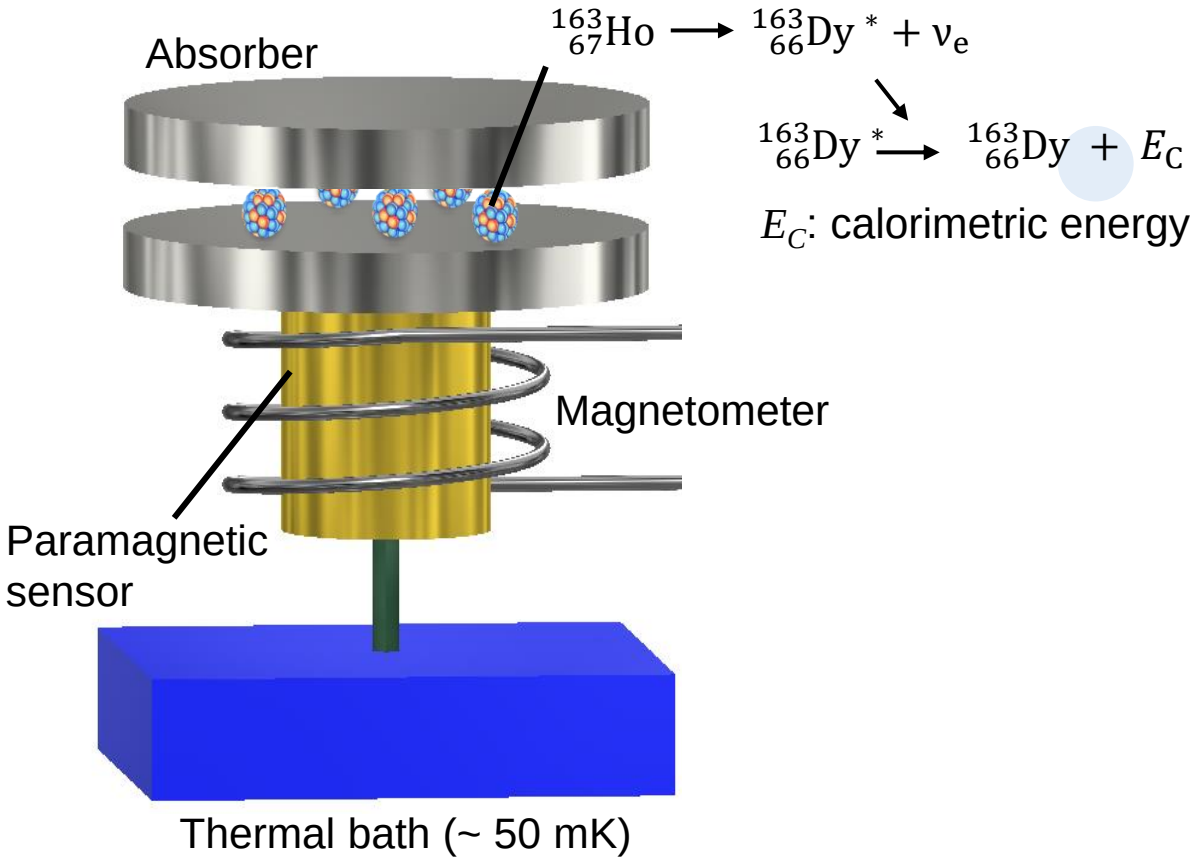
The Electron Capture in ^{163}Ho Project



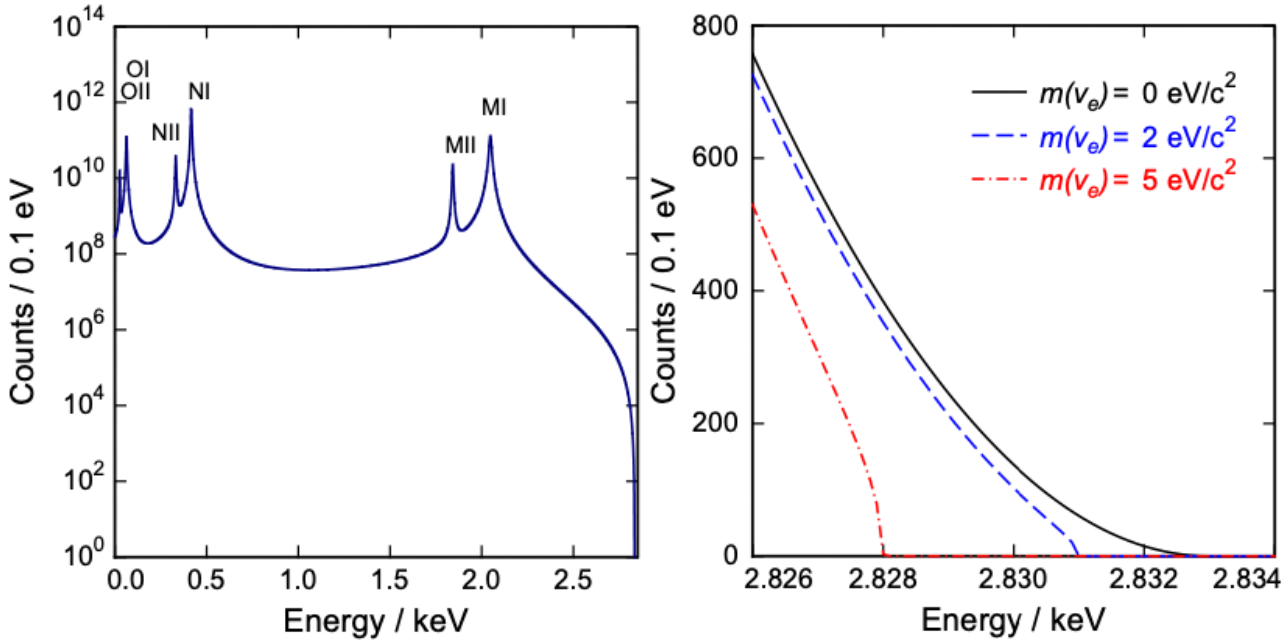
$$^{163}_{67}\mathrm{Ho} \rightarrow {}^{163}_{66}\mathrm{Dy}^{*} + \nu_e$$

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

E_C: calorimetric energy

Schematics of the **M**etallic **M**agnetic **C**alorimeter (MMC) [1,2]

Deriving the neutrino mass from the decay spectrum



Calculated ^{163}Ho electron capture spectrum [2]

[1] A. De Rujula *et al.*, J. High Energ. Phys., **15**, 2016, 6.
[2] L. Gastaldo *et al.*, Eur. Phys. J. Special Topics, **226,** 2017, 1623.

The Electron Capture in ^{163}Ho Project

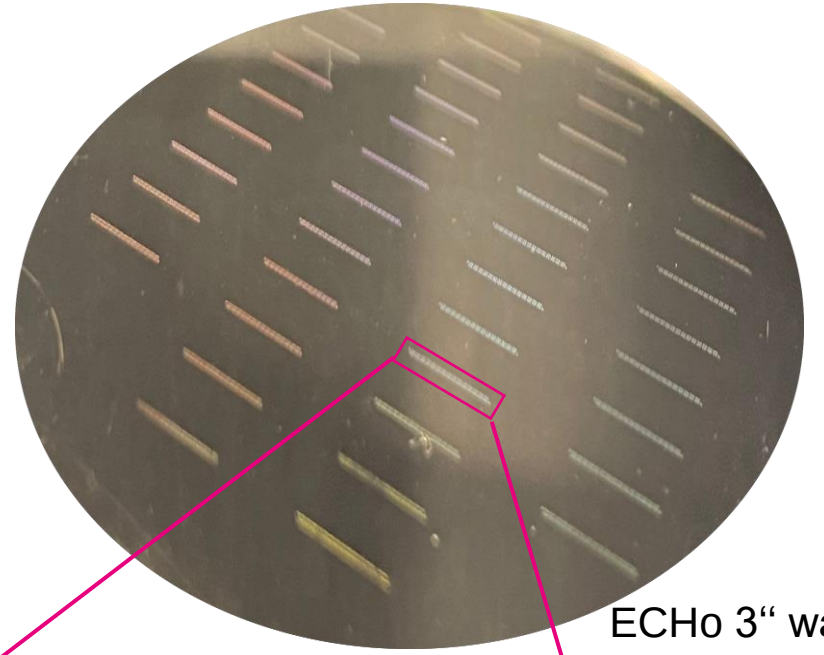
ECHo 1k → ECHo 100k

Implantation into a single MMC chip with 64 pixel

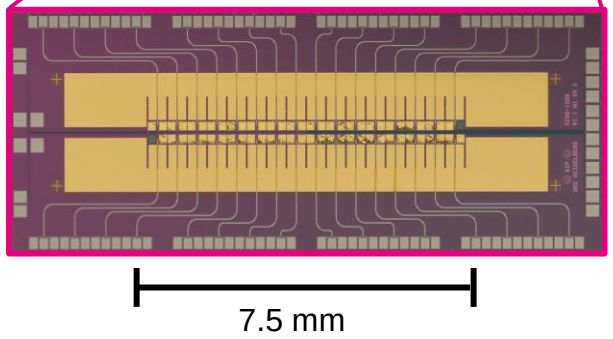
1 kBq ^{163}Ho
(2 x 10^{14} atoms)

Implantation into 3“ wafer with 40 MMC chips

100 kBq ^{163}Ho
(2 x 10^{16} atoms)



ECHo 3“ wafer with 40 times 64 MMCs



MMC chips for ^{163}Ho implantation

Requirements for source production:

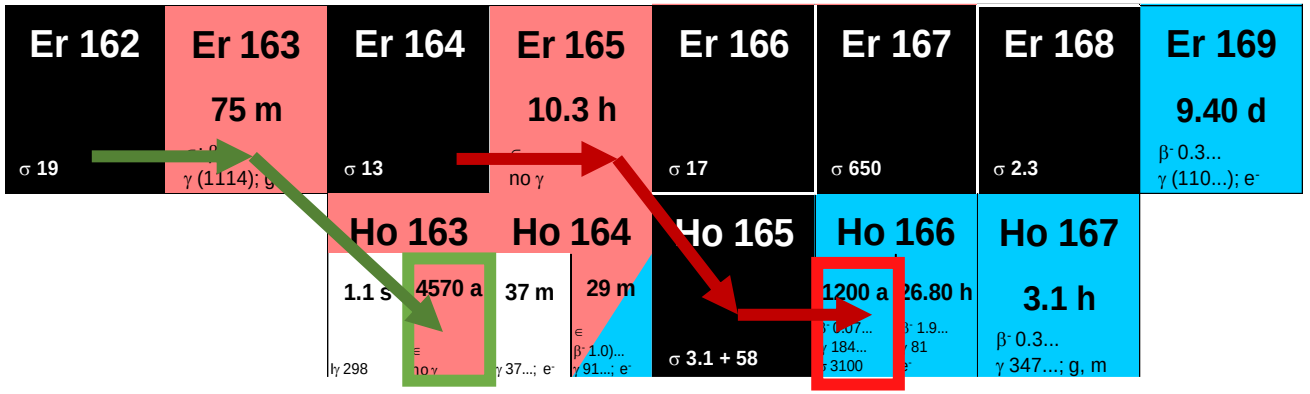
- ^{163}Ho to be implanted in 180 × 180 × 10 µm^3 silver absorber
- 10 Bq per MMC

Production of ^{163}Ho at ILL Grenoble

High flux reactor at the ILL in Grenoble, France.

Thermal neutron flux: ≤ $1.5 \cdot 10^{15}$ n cm^{-2} s^{-1}

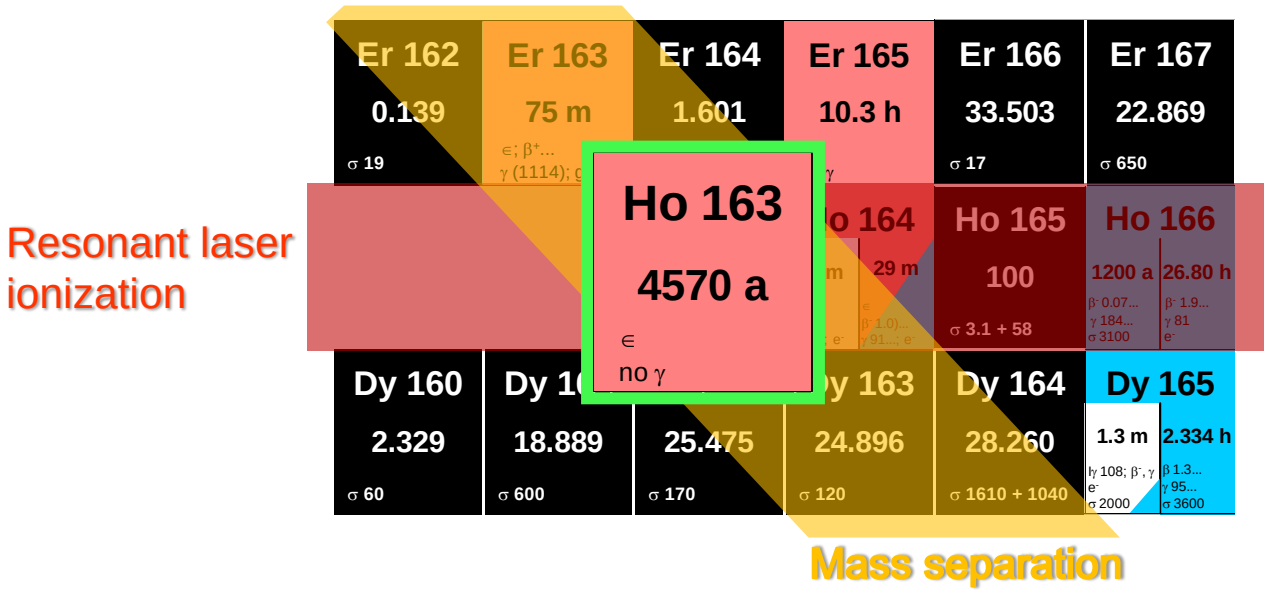
Neutron irradiation of an enriched ^{162}Er target



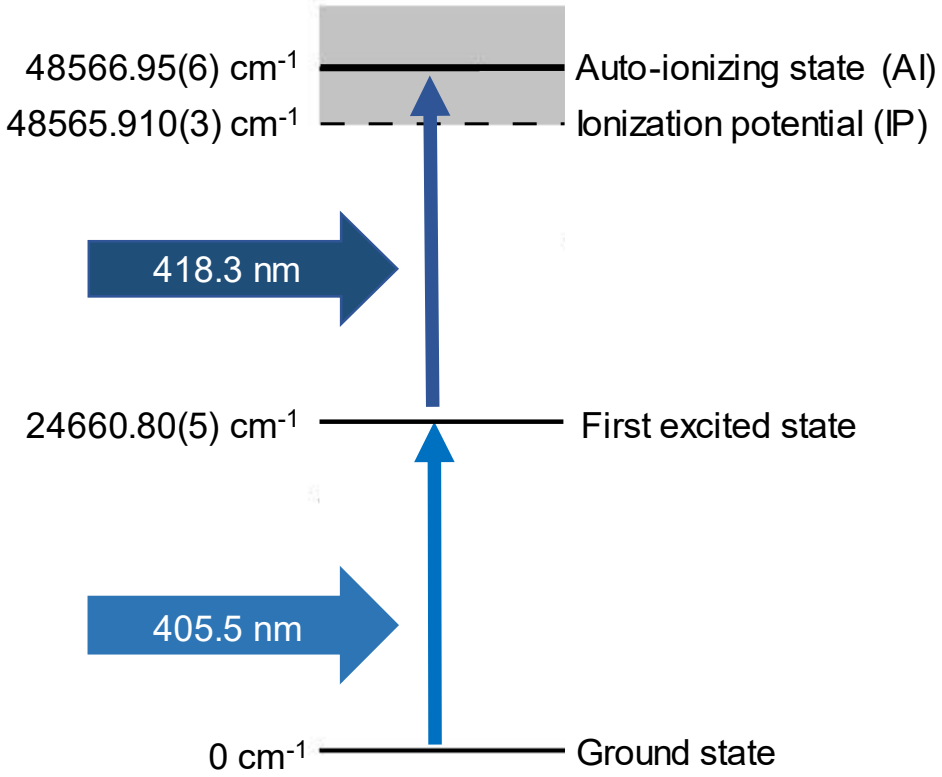
→ ~ $6 \cdot 10^{18}$ ^{163}Ho atoms (~ 30 MBq) generated for implantation into Absorbers

Resonance Ionization Mass Spectrometry

Resonant laser ionization
Mass separation
} Mono-isotopic ion beam



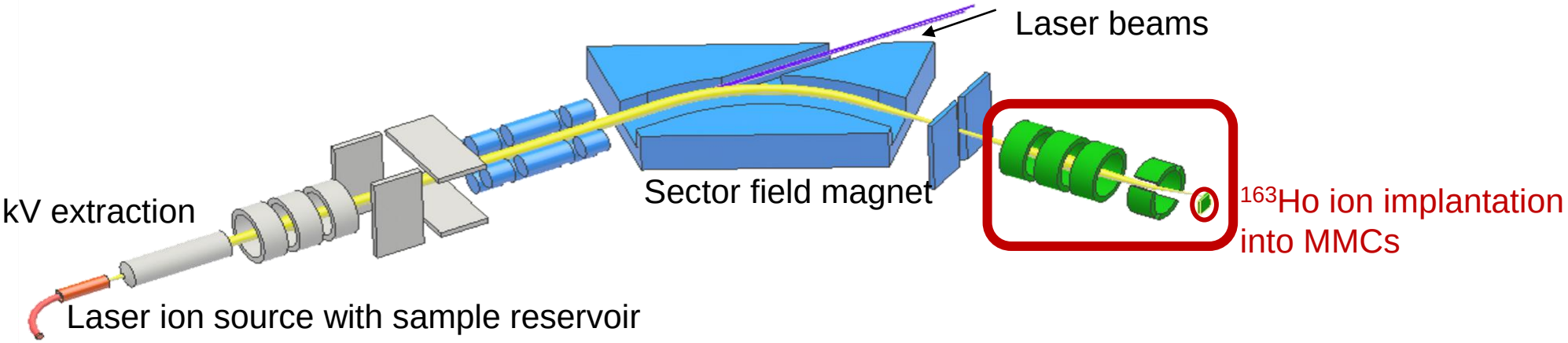
Resonant laser ionization

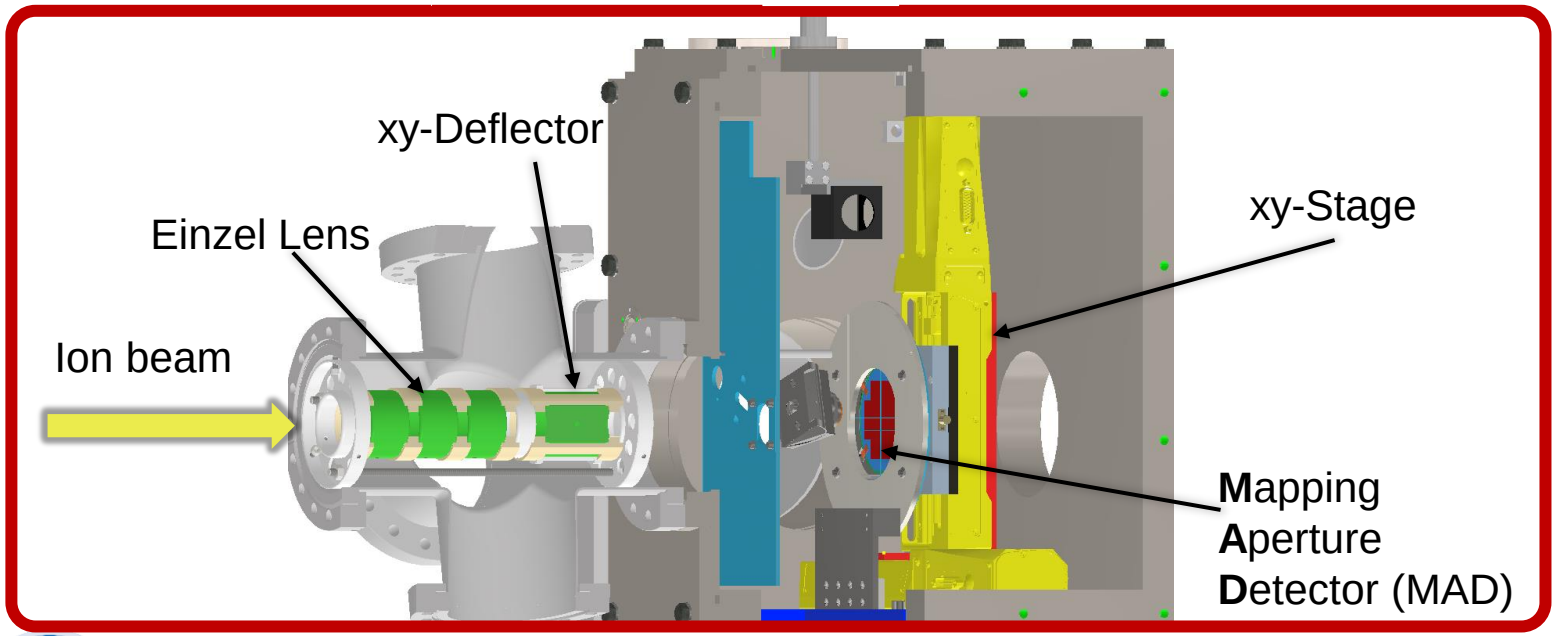


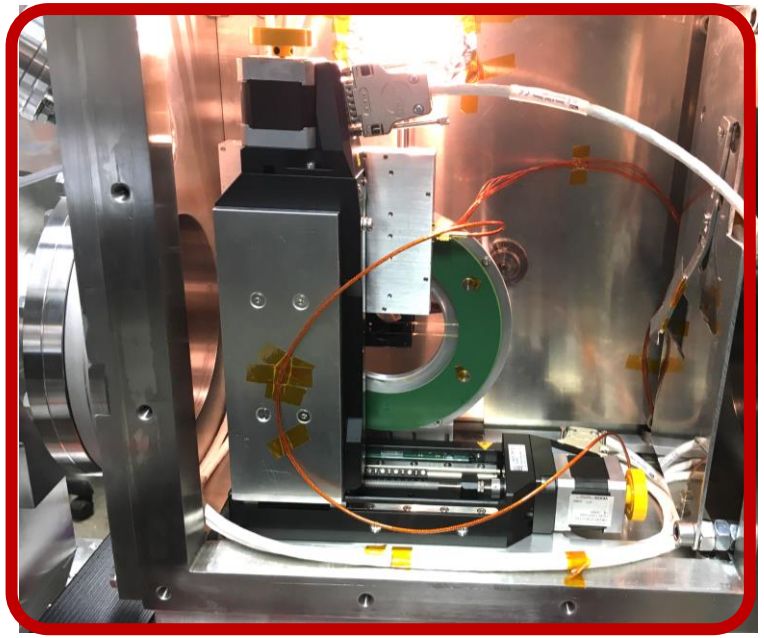
Efficiency: 69(9)% [1]

[1] T. Kieck *et al.*, Nuclear Inst. and Methods in Physics Research A**, 945,** 2019, 162602.

Mass separation and implantation at the RISIKO mass separator

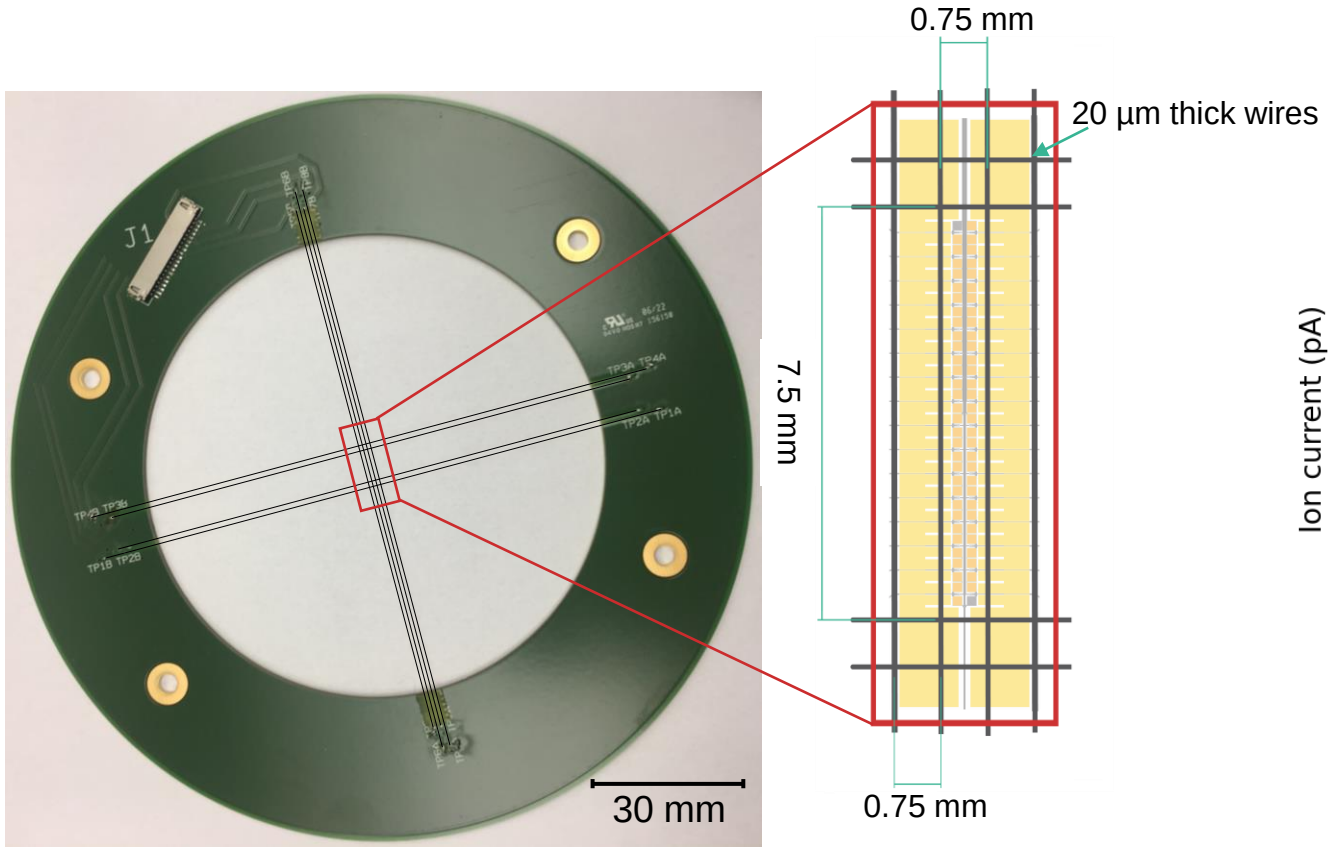






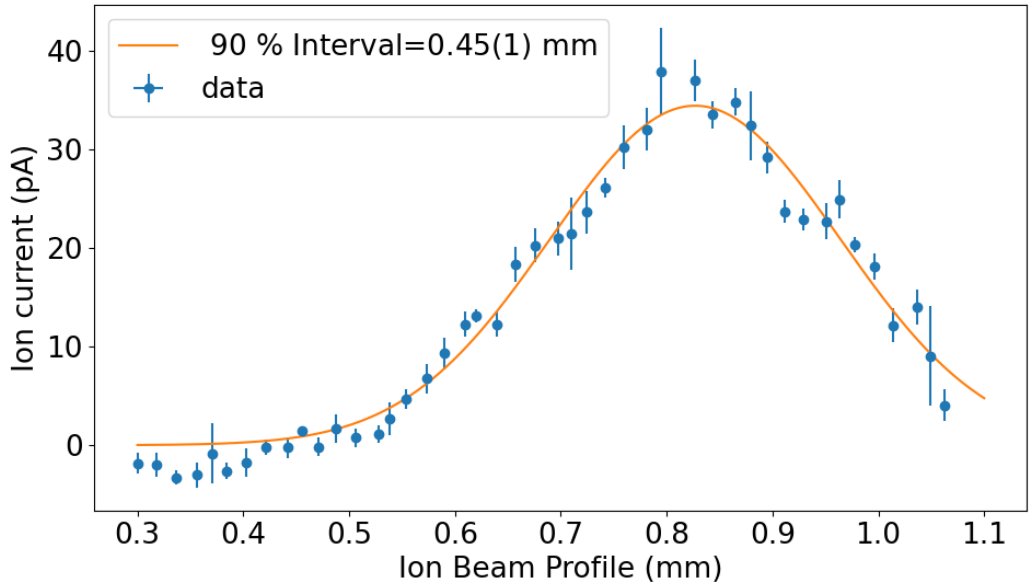
Mapping Aperture Detector

- Optimization and permanent ion beam control
- Ion beam characterization



Ion beam profile

Ion current: 20 nA



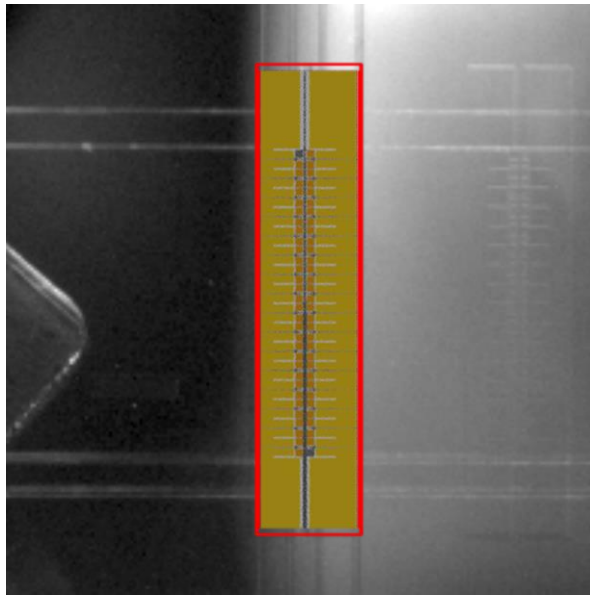
Implantation of an ECHo-100k wafer with ^{177}Lu

Verification of implantation accuracy by autoradiography

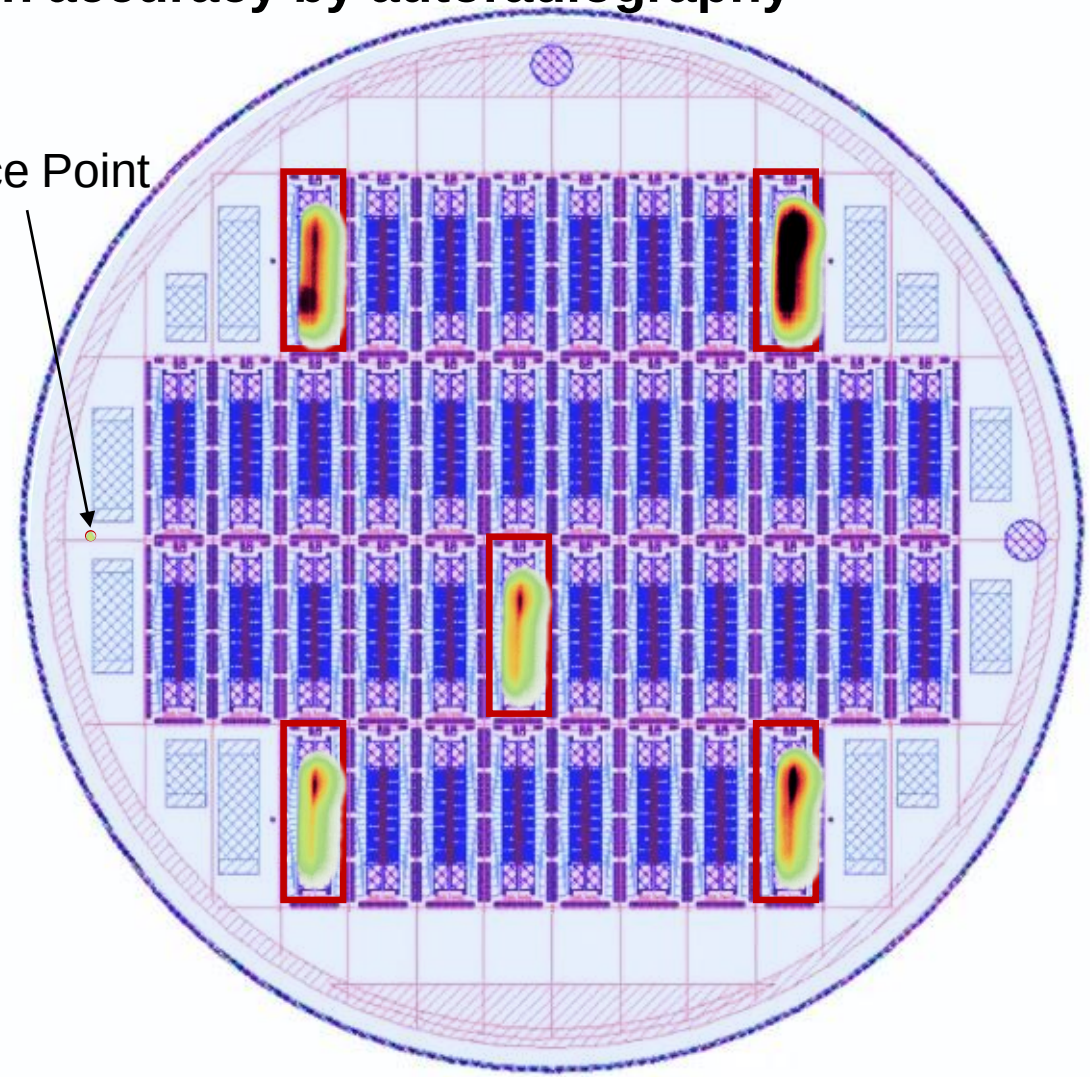
First implantation of a 3“ wafer at RISIKO

Lu 175	Lu 176	Lu 177
97.40	2.60	6.65 d

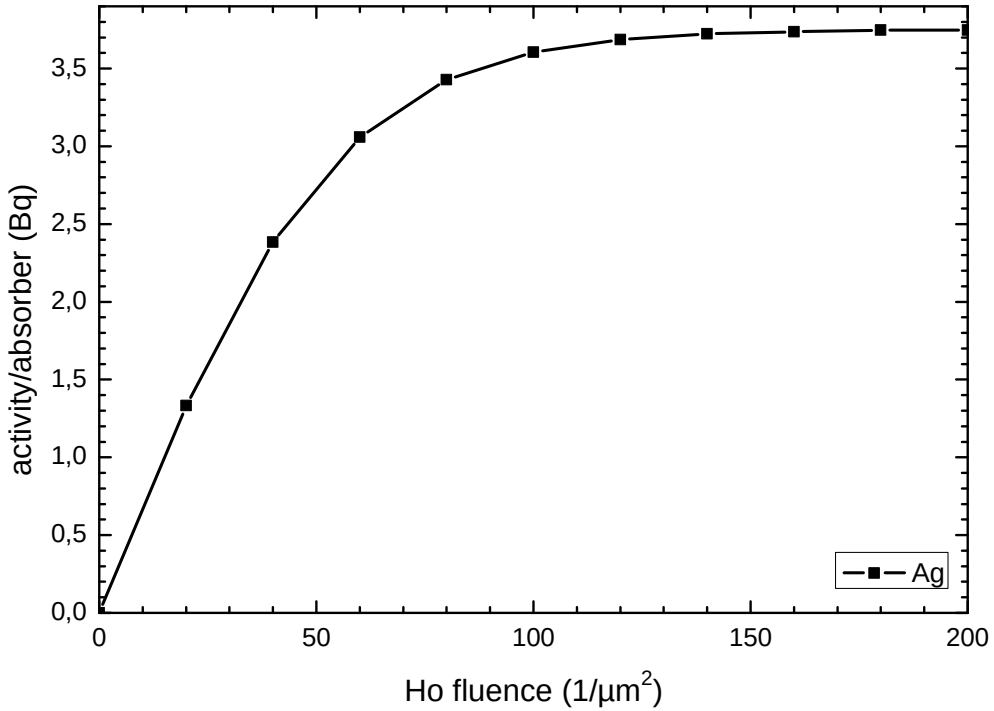
Position adjustment of the wafer with xy-Stage



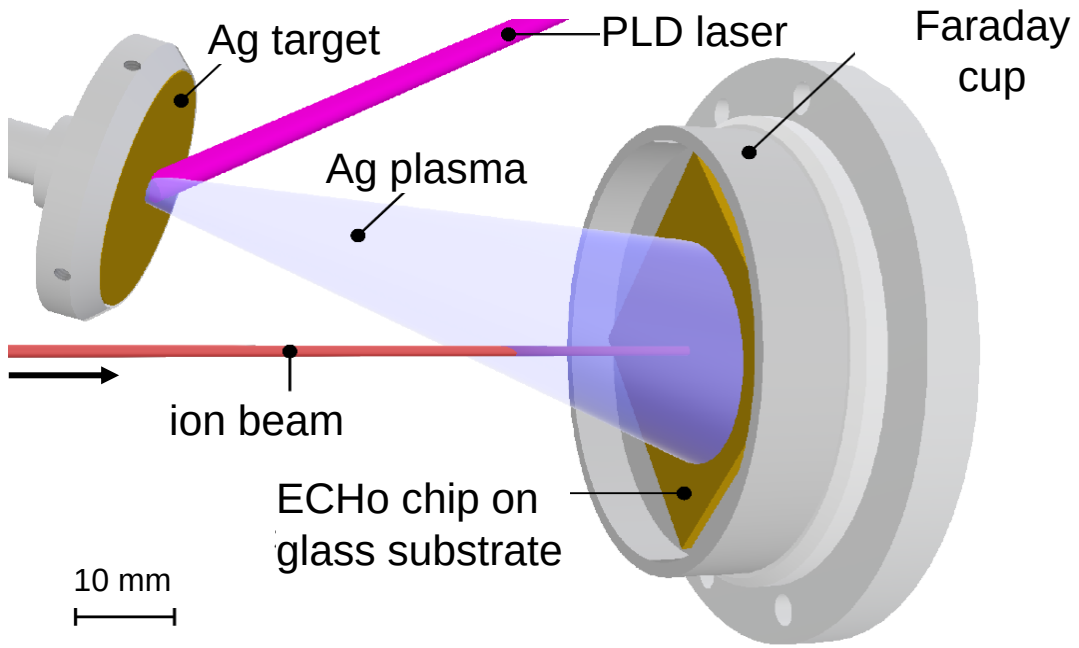
Reference Point



Pulsed Laser Deposition (PLD)



TRIDYN Simulation for Ho implantation in Ag [1]



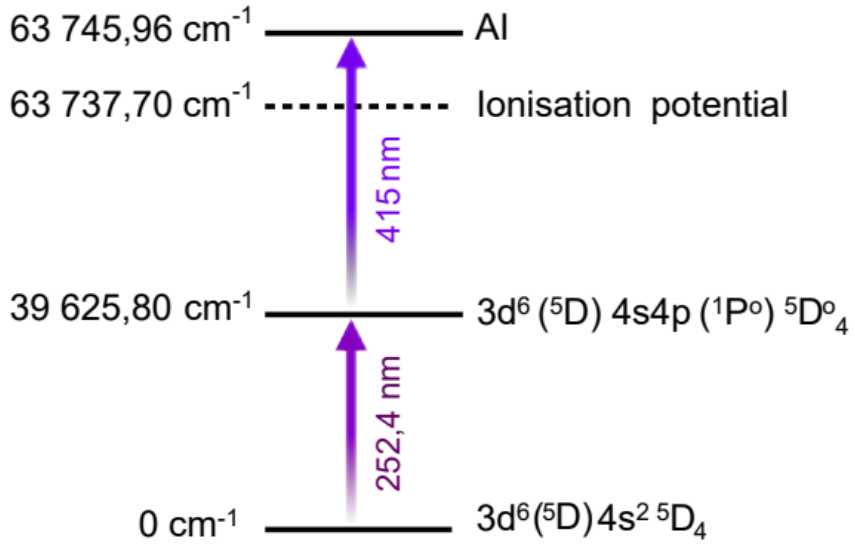
Sketch of PLD setup [2]

- Sputtering effects by ions with 30 kV
- 10 Bq per detector pixel
- PLD of 120 nm silver layer to compensate for sputtering effects
- Simultaneous deposition + ion implantation

[1] M. Möller *et al*., Nuclear Inst. and Methods in Physics Research B, **2**, 1984, 814.
[2] T. Kieck, PhD Thesis, 2019, JGU.

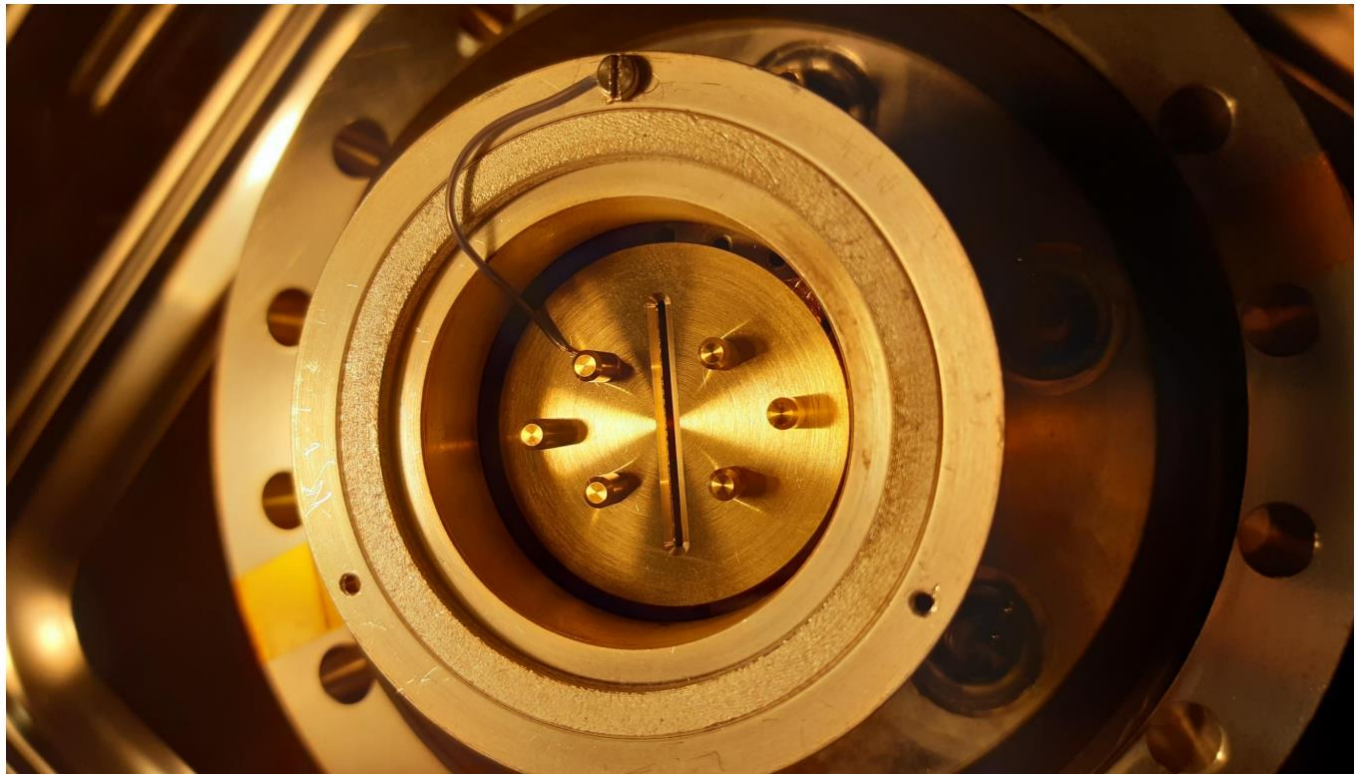
Implantation of ^{55}Fe into Absorbers

- Study of electron capture decay of ^{55}Fe for activity standardisation (Prima-LTD project)
- Goal: Implantation of 5 Bq per MMC pixel at RISIKO
- Two step elemental selective laser excitation scheme



Implantation of ^{55}Fe

- Implantation without PLD
- Conductive aperture for beam alignment
- Current on aperture measured



Implantation of ^{55}Fe

- Implantation without PLD
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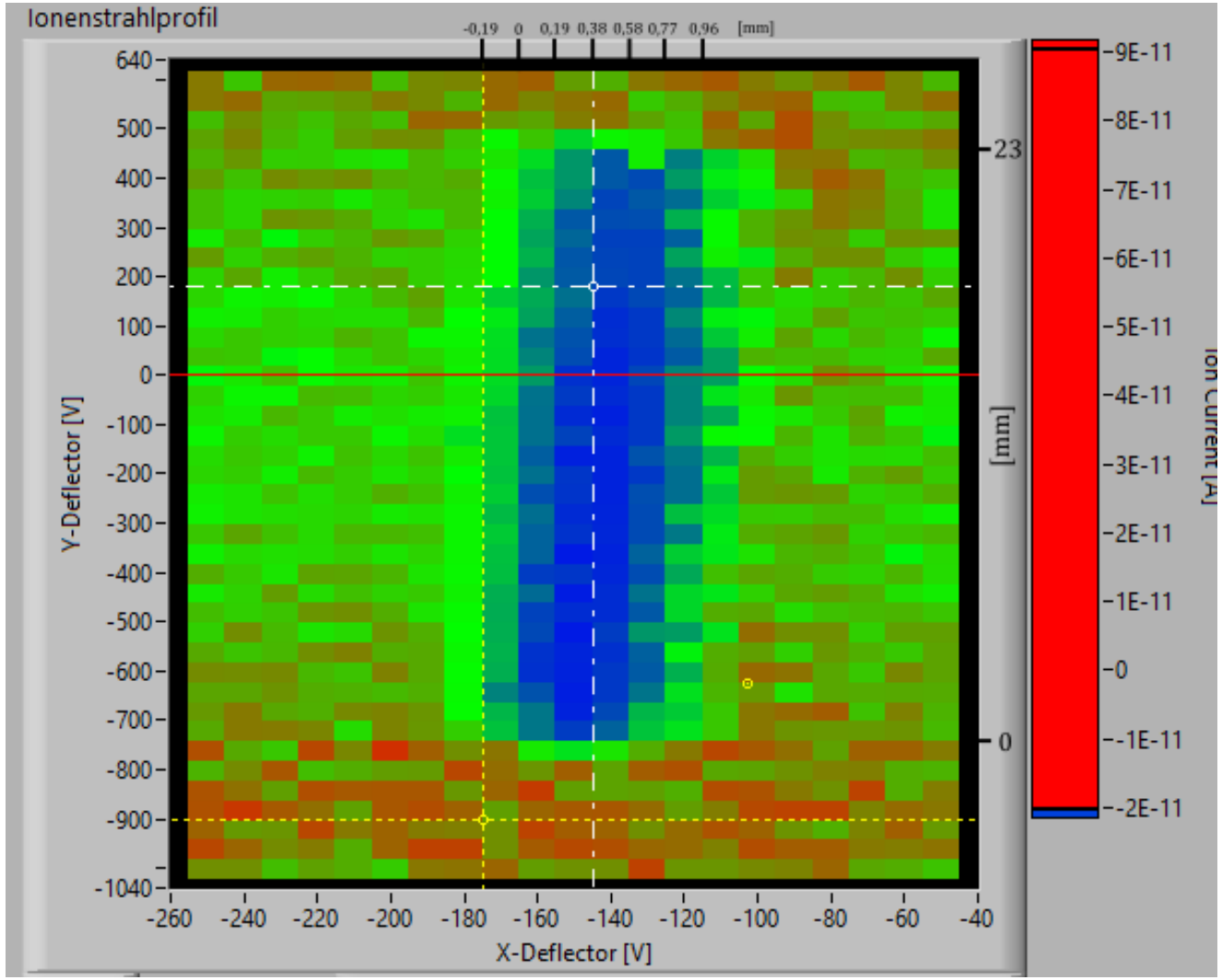
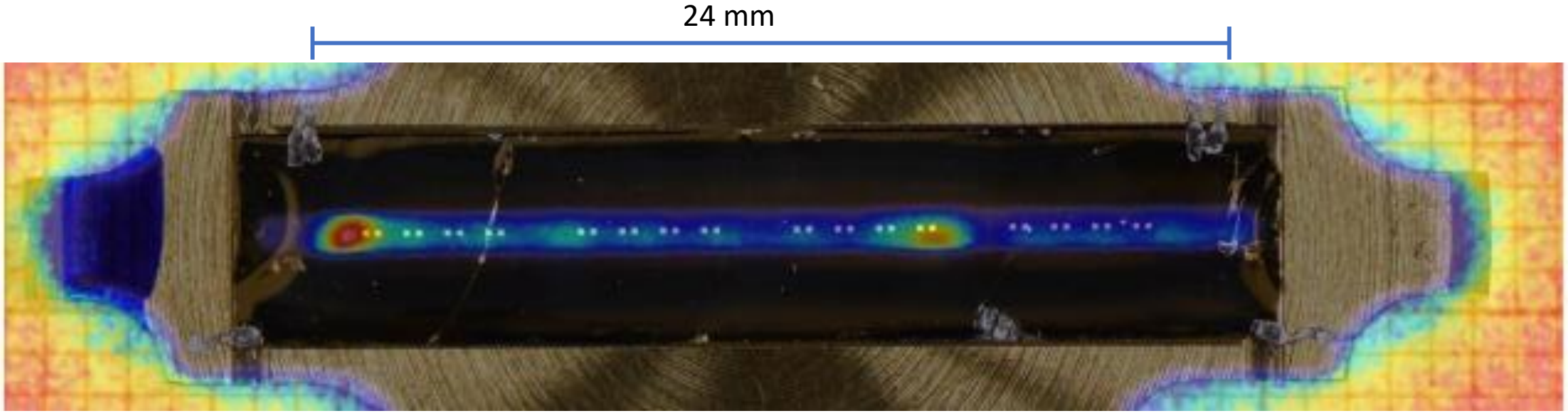


Implantation of ^{55}Fe

- Implantation result of
- Goal: 1 Bq per pixel
- Beamwidth < 1 mm



Conclusion

- High ionization efficiency of Ho at RISIKO
  → 70 %
- Implantation region of RISIKO upgraded for 3” wafer implantation
- Demonstration of the implantation quality on 3” wafers
  → Implantation of ^{177}Lu and autoradiography
- First implantation of ^{163}Ho into a 3” wafer – complications with PLD
- Successfull implantation of ^{55}Fe into 24 MMCs (no PLD required)

PRISMA+ DETECTOR LAB

ECHo

DFG Deutsche Forschungsgemeinschaft
Research unit FOR 2202/1 and 2202/2

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JG|U PrimA-LTD collaboration

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Thank you for your attention